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THE EFFECT OF REGULATION UNCERTAINTY ON WATER-RIGHT PRICES: THE CASE OF THE LOA BASIN IN THE ANTOFAGASTA REGION OF CHILE

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THE EFFECT OF REGULATION UNCERTAINTY ON WATER-RIGHT PRICES: THE CASE OF THE LOA BASIN IN THE ANTOFAGASTA REGION OF CHILE

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Abstract

This paper analyzes institutional arrangements that impose barriers to voluntary water transfers in the Loa basin, in northern Chile, and their impact on water prices in the market. We focus on restrictions imposed by the Chilean Water Authority (Dirección General de Aguas: DGA). These affect changes in water-diversion location and changes in the nature or type of water use.

We hypothesize that these restrictions help explain why mining companies instead of acquiring additional water rights in the market prefer desalination, in spite of the high relative prices. With data for the Antofagasta Region, in Northern Chile, we provide evidence to support this hypothesis.

JEL: Q13, Q15, Q25
Keywords: Desalination, Water Markets, Water Rights, Water Regulation.

Introduction

The growing pressure on fresh water resources has led countries in the past few decades to increasingly rely on water markets (Rosegrant and Binswanger, 1994; World Bank 1993). This is the case in western United States, Chile, Australia, South Africa and New Zealand. Moreover, other Latin American countries have been discussing policy reforms towards markets (Bauer, 2004).

The impact of water markets on water reallocation has been slow, however, in spite of much higher marginal values in urban, industrial and mining uses, as compared to irrigated-agriculture uses where most of the water rights are presently concentrated (J. Brewer, R.Glennon, A. Ker and G. Libecap, 2007). Institutional arrangements that impose barriers to voluntary water transfers help explain this anomaly (Eden, S. et al.

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2008). These arrangements have been developed to protect the environment and the interests of third parties from adverse impacts that may result from trade. The latter includes conflicts with other water rights, threats to public safety, and harms to public welfare (Eden, S. et al. 2008).

Examples of these arrangements that deter transactions are the need to get approval from the Water Authority when either the location or nature of the use is changed with the transaction; or when the Water Authority restricts the amount to be consumed by the new owner, not to the amount of rights held by the original owner, but to the amount actually consumed by him/her (Eden, S. et al. 2008).

Slaughter (2009) describes the process of water transfers saying: "… underlying decisions regarding resource allocation are taken through an on-going dance involving water users, environmental and other non-ownership interests, legislatures, State water agencies, and others." As Lund (1993) pointed out almost two decades ago, these arrangements cause uncertainty in water-transfer completion because regulators could decide not to approve the water transfer, court challenges could appear based on regulations or environmental concerns, and the threat of regulatory or court challenge could dissuade water buyers from continuing the pursuit of water transfers.

In this paper, we analyze institutional arrangements that impose barriers to voluntary water transfers in the Loa basin, in northern Chile, and their impact on water prices in the market. We focus on restrictions imposed by the Chilean Water Authority (Dirección General de Aguas: DGA). These affect changes in water-diversion location and changes in the nature or type of water use.

These restrictions affect the probability of getting final approval on the use of purchased water rights in another location, and, if obtained, the time to completion. Because these restrictions do not equally apply to all sectors, with mining facing the higher number of restrictions, these arrangements may cause water-right price differences among uses.

We hypothesize that these restrictions help explain why mining companies instead of acquiring additional water rights in the market prefer desalinated water, in spite of the high relative prices. With data for the Antofagasta Region, in Northern Chile, we provide evidence to support this hypothesis.

It is interesting to note that these restrictions exist despite the fact that water rights in Chile, once granted, are fully protected as private property rights under the Chilean

Constitution[2]; and that water rights under the 1981 Water Code are completely separated from land ownership, being subject to the general system of real estate title registration, to be freely bought, sold, mortgaged, and transferred, like other forms of real property.[3]

1. Some Stylized Facts about the Loa Basin

The Loa basin is part of the First and Second Regions, in northern Chile. It is an extremely arid area with the annual average precipitation ranging from 4 mm in Calama (altitude: 2,260 m.a.s.l.) to 146 mm in Lequena (altitude: 4,000 m.a.s.l.).

Northern Chile represents over one fourth of world copper production and is a relevant player in many other minerals. It has a growing urban population, is the home of indigenous populations with traditional agriculture, and is the site of valued ecosystems.

This study will focus on the Loa basin in Chile's Second Region, also known as the Antofagasta Region. This region covers 126.049 km^2 and by mid-2011 it had an estimated population of 581,701, according to the National Statistics Bureau (INE). The two main counties in the region are Antofagasta, with an estimated population of 372,973 people, and Calama with 148,784.

Mining is the main economic activity in the region, with 65% of the regional GDP and with copper as its main product. Agriculture represents less than 1% of the regional GDP and produces only for the local market. The importance of its approximately 2,000 hectares of irrigated land lies on its link to traditional agriculture and to indigenous communities in the area.

The hydrology in the Antofagasta Region is characterized by the Loa River and its two main tributaries: the Salado and the San Salvador rivers. The Loa River originates in the Andes and runs 440 kilometers across the extremely arid Atacama Desert to the Pacific Ocean, with an annual average flow that varies from 0.5 to 5 cubic meters per second (DGA 2001). The Loa River provides water to agriculture, mining, industry and human consumption. Water quality differs greatly between the two main rivers, Loa and Salado, the latter carrying a large load of naturally occurring arsenic.

[2] See Constitución Política de la República de Chile, article 19(24).
[3] See Mentor (2001).

Water for the different sectors is also provided by two non-connected groundwater aquifers (Houston and Hart, 2004). These aquifers are linked to surface waters in a bi-directional way. Surface waters are mainly fed by the aquifers, and percolation occurs from surface to groundwater sources (Houston, 2006). Regarding underground water sustainability, current evidence is not conclusive as to whether or not water is being extracted at higher or lower rates than aquifer recharges (Grosjean and Veit, 2005).

Additionally, there are more than 120 groundwater-fed wetlands that not only provide eco services, but also support some of the indigenous communities in the region (DGA, 2001).



Figure 1: Map of the Loa Basin, Chile.

2. The market for water rights and institutional constraints on water diversion location

Water rights granted in the Antofagasta Region between 1981 and 2010 reach 1.86 Million m^3/day: 0,69 Million m^3/day of surface water and 1.16 Million m^3/day of ground water (DGA, *Catastro Público de Aguas*).

As Table 1 shows, consumption is less than total rights granted in spite of very high water scarcity in the region. The reason behind the low relative consumption lies, at least partially, in institutional factors. As an example, mining companies today use only 48% of the water rights they hold (DGA, 2008) due to restrictions on the use of water.

Table 1**: Fresh** water consumption per economic sector in the Antofagasta Region

Economic sector	m^3**/day**
Agriculture & Livestock	285,811
Urban use	94,608
Industry	164,678
Mining	419,472
Energy	128,995
Other	29,117
Total Consumption	**1,122,682**

Sources: DGA, 2007. The source for mining is DGA, 2008.

Because the use of available water (surface water and groundwater) has been already granted, new water requirements need to be satisfied through the market or by the development of new water sources such as desalinated water.

The market today is one in which farmers, indigenous communities and mining companies trade water rights. In the analysis that follows, we use data on 102 surface water and 24 groundwater-right transactions occurring in the period from January 2005 to December 2009[4], recorded in the Property Registers of Loa and Taltal[5]. This

4 The 126 registers is the outcome of filtering a wider data set on more than 400 registers of the Property Registers of Loa and Taltal. The filters are: 1) The register is not due to a market transaction (such as inheritance, mergers). 2) The transaction includes other goods together with the water right (typically land). 3) The water right does not belong to the Loa basin. 4) The transaction is for a water flow of less than 4.3 m^3/day. 5) The use of the water right is not permanent and/or continuous through time. 6) There is no information on the water flow or the water flow unit is missing. 7) There is a family relationship between the buyer and the seller. 8) The transaction took place before 2005. 9) The transaction price is missing. 10) The reported price is clearly wrong (one case).

represents a total amount of 11,335.9 m^3/day of surface water with an average of 111.1 m^3/day per transaction, and a total amount of 52,249.5 m^3/day of ground water with an average of 2,177.1 m^3/day per transaction

Weighted average prices were US$0.1841 and US$0.9017 per cubic meter, for surface and ground water respectively.[6] Groundwater prices are higher than surface water prices because ground-water availability is more secure in the Loa basin. Nevertheless, as Table 2 shows, water-right prices are highly dispersed.

Table 2: Summary Statistics of Market Water-Right Prices, 2005-2009

	Surface Water		Ground Water	
	$US per m3/day	$US per m3*	$US per m3/day	$US per m3*
Number of Observations	102	102	24	24
Weighted Average	959,93	0,1841	4.701,66	0,9017
Weighted Standard Deviation	492,12	0,0944	6.051,64	1,1606

(*) Water-right prices in dollars per m3/day have been converted into dollars per m3 using a 7% discount rate and considering 365 days per year.

As already mentioned, water-right trading in the Antofagasta Region has been affected by the National Water Authority (DGA), that has established restrictions to changes in the location of ground and surface-water extractions.

Restrictions to changes in groundwater diversion location seek to avoid possible negative externalities on groundwater-fed wetlands and on surface water availability at specific locations. Restrictions on surface water diversion pursue to reduce third-party effects of trade, such as negative externalities on water quality. As an example, a change in the location of water diversion from the Salado River to some downstream location on the Loa River, after the place in which the Loa and the Salado meet, may affect the quality of water for some water users.

These restrictions to changes in the location of water extractions can affect the time the DGA takes to solve each application, and the likelihood of receiving a positive answer from the DGA. Public data from the *Catastro Público de Aguas* of the DGA indicate that during the period 1996 to 2009, the DGA approved only 16% and 47% of the applications for changes on extraction location of surface and ground water, respectively. The average time for the DGA´s decisions on these applications is 2.21

5According to Chilean law, these Property Registers (Conservadores de Bienes Raíces) provide official certification of legal tenure.

6 Original prices were in UF's per liter per second. This is a perpetual right. The UF or Unidad de Fomento is a non-circulating currency in Chile, which adjusts for inflation. Prices were translated into dollars per cubic meter, using the December 2011 average UF and dollar values, and a 7% rate of interest.

years in the case of ground water, and 3.63 years in the case of surface water. Table 3 summarizes the data for those applications.

Table 3. Applications for changes on extraction location of water in the Antofagasta Region, 1996-2009

	Surface water (m^3/day)	Time of resolution (days)	Ground water (m^3/day)	Time of resolution (days)
Total applications	42,206		390,372	
Approved by DGA	6,756	1,324.4	182,408	808.0
Denied by DGA	32,383		97,304	
Desisted by the applicant	3,067		54,432	
Pending at DGA	0		56,238	

Source: prepared by the authors with information from *Catastro Público de Aguas*, DGA.

Other restrictions to market activity come from environmental concerns. In fact, industries that acquire water to develop new projects need to carry out an environmental impact assessment.[7] In the Antofagasta Region, mining is the main industry and there are cases where a mining company has bought water rights, not being able to use them after the environmental agency rejected the project[8].

These constraints in the Antofagasta Region create market segmentation with most transactions of surface water taking place within a canal, where changes in the point of extraction do not need DGA approval.

3. The use of sea water

The lack of new water rights in the Loa basin, together with the constraints to market activity, help explain not only why mining companies use only 48% of the water rights

[7]This does not apply to agricultural projects.
[8]As an example, the mining company Quadra Minino bought underground water in 2008 in the Pampa Llalqui, 30 kilometers from Calama, for around US$40 million, but has not been able to use it because of environmental reasons.

they hold but also their increasing demands for secure substitutes such as desalinated sea water or just sea water. In the future, fresh water from adjacent regions may also come in to meet mining needs.

As Table 4 shows, current production of desalinated water includes Minera la Escondida, with a capacity of 45,360 m^3/day, Aguas Antofagasta with 51,840 m^3/day and Esperanza Mining, of Antofagasta Minerals, with 4,320 m^3/day. Expected production of desalinated sea water for year 2019 reaches 472,090 m^3/day, and it represents approximately 25% of the total amount of water flows granted through permanent and continuous-use consumptive water rights in the Second Region.

Table 4: Current and expected use of desalinated sea water in the Antofagasta Region (in m^3/day)

Firm	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Escondida Mining Co., Coloso Plant (a)	45.360	45.360	45.360	45.360	45.360	45.360	45.360	45.360	45.360	45.360
Escondida Mining Co., Coloso Plant Enlargement							55.296	110.592	221.184	276.480
Aguas Antofagasta, La Chimba (b)	51.840	51.840	51.840	51.840	51.840	51.840	51.840	51.840	51.840	51.840
Aguas Antofagasta, Southern Desalination Plant (b)		86.400	86.400	86.400	86.400	86.400	86.400	86.400	86.400	86.400
Antofagasta Minerals, Esperanza (b)	4.320	4.320	4.320	4.320	4.320	4.320	4.320	4.320	4.320	4.320
Quadra Mining Co., Sierra Gorda Project (c)			5.443	5.443	5.443	5.443	5.443	5.443	5.443	5.443
Michilla Mining Co. (d)	2.246	2.246	2.246	2.246	2.246	2.246	2.246	2.246	2.246	2.246
TOTAL	103.766	190.166	195.610	195.610	195.610	195.610	250.906	306.202	416.794	472.090

Sources: (a) **"**Gestión del recurso hídrico y la minería en Chile". Water consumption in copper production expected for the period 2009-2020. (b) Information provided by Aguas Antofagasta. (c) Environmental Assessment report for "Proyecto Sierra Gorda", Minera Quadra Chile Ltda, pp. 2-41 and 2-42. (d). "Good practices and water efficiency in the Mining Industry", Cochilco, October 2008.

Desalination costs depend on several factors including technology used, plant capacity, site characteristics, water quality standards, regulatory requirements, construction and financial costs, and the variable costs associated with labor, chemicals, maintenance and energy.

Table 5 summarizes costs reported in the literature for a variety of reverse-osmosis desalination projects. Plant capital and water production costs decrease significantly as a function of capacity and for smaller desalination units the cost of seawater desalination shows higher variability.

Table 5. Reverse Osmosis Seawater Desalination Costs

	Size of Plant (m^3/day)	**Total cost (US$/ m^3)**
Karagiannis and Soldato (2008)	15.000-60.000	0,48-1,62
	100.000-320.000	0,45-0,66
Wittholz, O´Neill, Colby and Lewis (2008)	50.000	0,70
	275.000	0,50
	500.000	0,45

Table 6 shows investment and operating desalination costs by reverse osmosis in the northern part of Chile. The estimation was made by the authors based on information from different sources. Operating Costs represent in the order of 55% of total costs, while electricity is by far the most important of the operating costs, assumed to represent 80% of such costs at present[9].

Table 6. Reverse Osmosis Seawater Desalination Costs in Chile

		Size of Plant (m^3/day)	**Total cost (US$/ m^3)**
Estimated cost (2011)	Case 1	45,360	0,85
	Case 2	86,400	0,81

[9] Case 1 assumes an investment of US$70 million, a useful life of 20 years and no residual value (Cochilco (2008)). Case 2 corresponds to a plant developed by Aguas Antofagasta in the southern part of Antofagasta named "Planta Desaladora Sur Antofagasta". It assumes an investment of US$120 million, a useful life of 20 years and no residual value. (Presentation before the "Servicio de Evaluación Ambiental",Corporación Nacional del Medio Ambiente). To estimate the capital costs involved, a rate of discount of 7% was assumed. This is the rate of discount used to determine urban-water prices in Chile. According to Cochilco (2008) the cost of electricity represents 80% of the operating costs with a consumption of 3,4KWh/ m^3. The cost of the KWh was calculated by the authors using the average marginal cost of electricity in the northern part of Chile for 2011 (US$/KWh 0,092, source Centro de Despacho Económico de Carga-Sistema Interconectado Norte Grande) and the capacity cost used in April 2011 for calculating the regulated price for consumers (US$/KWh 0,0137, source Comisión Nacional de Energía). The plant capacity factor was assumed at 90%.

Desalination costs also depend on the geographical and altitude location of the place in which desalinated water is used. In the case of the mining industry in northern Chile, pumping to reach the mines is a major component of total cost.

As Table 7 shows for two projects in the region, for an altitude of 3,150 m.a.s.l. and a plant size of 45.360 m^3/day, the pumping cost is approximately US$ 2.91 per m^3 (capital costs are US$ 1.25 per m^3 and operating costs are US$ 1.65 per m^3), increasing the production cost of desalination from US$ 0,85 per m^3 to US$ 3.76 per m^3[10]. Energy is again the most important of the operating costs of pumping, assumed to represent 90% of such costs. For a plant size of 10.368 m^3/day and an altitude of 900 m.a.s.l.[11], the total cost of desalination, pumping included, is estimated at US$ 2,47 per m^3.

Table 7. Reverse Osmosis Seawater Desalination and pumping Costs in Chile

	Size of the Plant (m^3/day)	Desalination Costs (US$/ m^3)	Pumping Costs (US$/ m^3)	Total Costs (US$/ m^3)
Case 1: pumping from 0 to 3,150 m.a.s.l.	45,360	0.85	2,91	3,76
Case 2: pumping from 0 to 900 m.a.s.l	10,368	Na	Na	2,47

4. Water-right prices and Desalination costs

Data on market water-right prices shows that in the case of surface water, they are but a fraction of the cost of desalination, specially if pumping is considered. The weighted

[10] Case 1 assumes an investment of US$220 million for the pumping infrastructure (4 pumping bombs), a useful life of 20 years and no residual value (Cochilco (2008)). To estimate the energy costs of desalination and pumping we used the data from Cochilco (2008): 3,4 kWh/m^3 in the desalination process and 14 kWh/ m^3 for pumping. To estimate the capital costs involved, a rate of discount of 7% was assumed.

[11] Case 2 corresponds to a plant developed by Mantoverde mining company (belonging to Anglo American). It assumes an investment of US$ 62 million for the desalination plant and the pumping infrastructure (2 pumping bombs for an altitude of 900 m.a.s.l.), a useful life of 20 years and no residual value. (Presentation before the "Servicio de Evaluación Ambiental", Comisión Nacional de Medio Ambiente). To estimate the energy costs for the desalination process we used the data from Cochilco (2008): 3,4 kWh/m3. For pumping, we estimated a value of 4 kWh/m3 which is proportional to the value used by Cochilco (2008) of 14 kWh/ m^3 for pumping water to an altitude of 3,150 m.a.s.l. To estimate the capital costs involved, a rate of discount of 7% was assumed.

average price of US$ 0.1841 per cubic meter for surface water represents only 22% of the desalinated water cost of US$ 0.85 per cubic meter. In the case of groundwater, the weighted average price of US$ 0.9017 per cubic meter, is 5% higher than the cost of desalination. The question to be addressed in this section is whether or not water-right prices are related to desalinated water costs, including pumping, through an observable mechanism.

In equilibrium, if the approval of the change in water diversion location were certain, with no delay in the process, then desalinated water and water from water rights should, in principle, exhibit the same price, provided that water-supply risks are the same for all sources. At any given location where both desalinated and freshwater are used, the price of a water right and the price of desalinated water, including the required pumping up to the specific location, should, in principle, be equal, in dollars per m^3.[12]

If the approval is not guaranteed and/or it is not automatic without delay, then the current value of a cubic meter from a water right should equal its expected value T years from now, when the new location is finally approved or rejected, discounted at the appropriate rate of discount. If approved, a water-right cubic meter will be valued at a price equivalent to its desalinated counterpart at time T. If the new location is rejected, only a percentage of the original value will be recovered. Thus we have that:

$$P_{WR} = \frac{p\, P_{DW}}{(1+r)^T} + \frac{(1-p)\, \alpha\, P_{WR}}{(1+r)^T}$$

where P_{WR} and P_{DW} represent the market prices of one cubic meter of fresh water and of one cubic meter of desalinated water respectively, in dollars per cubic meter; p is the probability that the new location will be approved; T is the time until a final decision on approval or rejection is made, assumed constant and known in this model at its expected value; and α is the percentage of the water-right value which may be recovered if the new location is rejected. It is assumed that a water right bought today cannot be used before a final decision on approval or rejection is made.[13]

If the new location at time T were certain, p would equal 1 and the only difference between a water-right cubic meter and a desalinated cubic meter would be the rate of discount.

[12] The unit of measurement behind water right prices is typically "dollars per m3/day". These have been converted into dollars / m^3 using a 7% discount rate and considering 365 days per year.
[13] It may be useful to note that the equation is also valid if prices are in dollars per m3/day in perpetuity.

On the other hand, if changes in location were impossible or close to impossible, then p would near zero, and α would be close to $(1+r)^T$, which is greater than one. This apparent contradiction is explained by the fact that the term P_{WR} assumes a delay in the diversion location decision, while αP_{WR}, on the right-hand side of the equation, assumes immediate water-right use, once the decision on location is final.

The question we will now address is, given the water-right price of 0.1841 dollars per cubic meter for surface water and 0.9017 dollars per cubic meter in the case of ground water, what would the desalinated-water price have to be in order to be indifferent between the different sources?

To answer this question, we will assume that the probability of approval is 16.01% for surface water and 46.73% for ground water, consistent with the findings of Table 3.

We will also assume, consistent again with Table 3, that the time to completion is 3.63 years in the case of surface water and 2.21 years in the case of ground water.

Finally, a recovery rate, α, of 20% will be assumed in case the application for a change in location is rejected. This is the value water would have if it is forced to stay in agriculture, the main seller today in the market. Since this value, it must be recognized, is only the authors' best guesstimate, sensitivity analysis will be performed in the range of 10-30%.

Table 8 shows the resulting marginal willingness to pay for desalinated water, given surface and groundwater-right prices.

Table 8: Marginal Willingness to Pay for Desalinated Water, as Derived from Fresh Water Prices

		Surface water	Groundwater
Water right price, Pwr (dollars per cubic meter)		0,1841	0,9017
Rate of discount, r		7,0%	7,0%
Time until final decision is made, T (in years)		3,63	2,21
Probability of transfer approval		16,01%	46,73%
Equilibrium desalinated-water price (dollars per cubic meter)	$\alpha = 0{,}1$	1,37	2,14
	$\alpha = 0{,}2$	1,28	2,04
	$\alpha = 0{,}3$	1,18	1,93

As Tables 5 and 6 showed, total costs of desalinated water ranged from US$0,81 (or US$0,85) per cubic meter when no pumping is required, as would be the case in the city of Antofagasta which is at sea level, to US$3,76 per cubic meter, if elevation up to 3,150 m.a.s.l. is needed. Current water-right prices are then consistent with desalination and relatively low pumping levels.

At this point, it is interesting to note that mining companies today are both using desalinated water and building desalination plants, for use at altitudes much higher than suggested by the model presented. This means that observable variables, approval probabilities and time to completion, only go so far to explain price differences. One possible explanation is the fact that approvals to changes on extraction location have become harder to obtain, due to increased environmental concerns. This is suggested by the data on approvals. Another possible explanation is that desalinated water is not dependent on water flows, and that mining companies are willing to pay a premium to eliminate this risk.

5. Conclusions

In an environment where water rights are allocated and protected by Law, and where there is a market where they can be traded, this paper illustrates the impact of other regulatory norms on prices, volumes traded and the allocation of water-related rents.

This is the case of the Antofagasta region (Region II) in Chile, in the Loa Basin, where regulations from the water authority *Dirección General de Aguas* restrict water-diversion changes.

Said regulations have forced mining firms to use desalinated water at a higher cost compared with fresh water, causing uncertainty among prospective buyers and hindering the exchange of water rights. This has prevented farmers and indigenous communities—who own water rights—from capturing economic rents associated to the differential between the private marginal value of water used in farming or in mining.

Data on 102 transactions of surface water rights and 24 transactions of groundwater rights performed between January 2005 and December 2009, together with available information on the cost of desalinating sea water and pumping it to different elevations above sea level, yield that the cost of desalinating and transporting one cubic meter of seawater to 3,150 m.a.s.l. is 20.4 times the price of surface water and 4.2 times the price

of groundwater. These differentials may be used to proxy the magnitude of the effects of regulations limiting the transfer of water rights across geographic zones, and also of the lost economic rents by farmers and indigenous communities.

Since mining companies have the option of using fresh water or desalinated seawater, our analysis uses a model that assumes that, in equilibrium, the present value of one fresh water right equals the expected value of said right going forward in time once it is revealed whether its transfer from its origin has been approved or denied. If approved, its value will equal the price of desalinated water; if denied, its value will be substantially lower than its current value.

Assuming that the value of water rights in case transport is denied varies between 10% and 30% of the initial value, and that the time of response and the probabilities of approval or denial are equal to the average times of response and percentages of approval and denial over the period 1996-2009, the paper concludes that the current prices of water rights are consistent with the cost of desalinating and pumping this water to not very high elevations. In other words, for surface water, the prices of water rights are consistent with a cost of desalinating and pumping in the range of US$ 1.18 – US$1.37 per cubic meter, and for groundwater, between US$1.93 and US$2.14. The evidence that there are at present mining companies consuming—or building facilities to use—desalinated water at higher elevations than those derived from the model, shows that the model can explain only part of the price differentials driven by these regulations.

The remaining differences could be explained by a more secure supply of desalinated seawater compared with natural sources, leading mining companies to be willing to incur a higher cost; by the fact that approvals to changes in diversion location have become harder to obtain; and by the fact that restrictions to transfer water away from the point of water diversion are imposed not only by the *Dirección General de Aguas*, but also by the Environmental Authority. Accordingly, the probability of obtaining approval for the transfer is today even lower than obtained in this paper.

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