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# Are Two Economic Instruments Better Than One?
## Combining Taxes and Quotas under Political Lobbying

**by**

**Israel Finkelshtain, Iddo Kan and Yoav Kislev**

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**Abstract**

Direct commands, market based, or combined, whichever is the government's mean of intervention, is expected to raise political lobbying and pressure. This study offers a political-economic model of an industry, which is regulated by an integrated system of both direct and market based policies. The model is used for a normative theoretical analysis and as a basis for a structural econometric framework. Exploiting a unique data set that describes the regulations of irrigation water in Israel during the mid eighties by means of quotas and prices, the political and technological parameters of the model are structurally estimated and used to assess the relative efficiency of quotas, prices and integrated regulation regimes.

**Key words:** Political Economy, Natural Resources, Water

**JEL classification**: D72

## I. Introduction

Recent decades of population and income growth have aggravated environmental problems and have led to over utilization of natural resources in many parts of the world. These concerns are increasingly leading policy makers to reinforce the traditional arsenal of command-and-control regulations with market based policies, such as user and polluter charges (OECD 2009). This tendency is strengthened by the promoted principle of cost recovery. As a result, the prevailing regulations in many countries are a mixture of direct and market based instruments. Prominent examples include the 1990 clean air act in the U.S. that involves polluting standards and charges (EPA 2001) and the regulation of water markets world-wide by means of quotas and user charges (EPA 2004).

Direct commands, market based or combined, whichever is the government's mean of intervention, is expected to raise political lobbying and pressure. This study offers a political-economic model of an industry, which is regulated by an integrated system of both direct and market based policies. The model is used for a normative theoretical analysis and as a basis for a structural econometric framework. Exploiting a unique data set that describes the regulations of irrigation water in Israel during the last three decades by means of quotas and prices, the political and technological parameters of the model are structurally estimated and used to assess the relative efficiency of quotas, prices and integrated regulation regimes.

The paper belongs to a long tradition of studies of environmental and resource regulation under political lobbying that commence with the prominent study of taxes and quotas by Buchanan and Tullock (1975). More recently, Fredriksson (1997) compares taxes versus subsidies in pollution control; Finkelshtain and Kislev (1997) examine the relative robustness of quantity versus price regulations to political influence; Finkelshtain and Kislev (2004) applied the Grossman and Helpman (1994) general equilibrium model to analyze alternative subsidy and tax regimes in the presence of politically powerful interest groups; Yu (2005) studies environmental protection and direct and indirect political influence; finally, Roelfsema (2007) investigates strategic delegation of environmental policy making. However, to the best of our knowledge, the political equilibrium under a mixed policy regime of direct and indirect controls and heterogeneous population is an as-yet unexplored area in this literature.

When an industry is regulated by integrated control systems the intensities of lobbying associated with the two economic instruments depend on the levels of each other. For instance, if both taxes and quotas are high enough, lobbying for larger quotas may vanish due to ineffectiveness of the quotas; and vice versa, a combination of low tax and quotas may turn the tax redundant. These specific cases are termed, respectively, 'pooling-quotas' and 'pooling-price' equilibrium. When both controls are effective, a 'separating equilibrium' appears: the population is divided into two interest groups; each is bounded by a different instrument, and hence, accordingly acts in the political arena. The division of agents among the groups is affected by the levels of the controls.

The theoretical model constitutes a basis for a structural econometric estimation of political and technological parameters. Specifically, it enables simultaneous estimation of both the weight put by a government on political rewards relative to the social welfare and the level of free-riding in the industry's lobbying efforts. Apart of the pioneering work by Zusman and Amiad (1977), and Lopez (1989), most of the structural empirical estimations of political parameters are based on the "Protection for Sale" model of Grossman and Helpman (1994). Various applications of this model share the same outcome: policy makers are found valuing social welfare highly relative to political contributions (Goldberg and Maggi 1999, Gawande and Bandyopadhyay 2000, Eicher and Osang 2002, Mitra, Thomakos and Ulubasoglu 2002, McCalman 2004, Gawande and Krishna 2005, Gawande and Hoekman 2006 and Facchinia, Van Biesebrock and Willmann 2006). This discovery surprised many researchers, particularly given that most of these studies report on extensive investment in lobbying. Various extensions of the model has been suggested for reconciling this apparent contradiction between the broad support for lobbying pressures and irresponsive governments; among them are Gawande and Krishna (2005) and Gawande and Hoekman (2006), who account for import-competing industries and policy uncertainty, respectively, as well as endogenous lobby formation, as theoretically developed by Mitra (1999) and Magee (2002), and empirically applied by Bombardini (2008). Gawande and Magee (2010) offer to settle the dilemma by enabling industries to be only partially represented in the political arena. They estimate a free-riding parameter which corresponds the public-good nature of trade barriers—it measures the level of distinction between cooperative lobbying, in which one lobby acts to maximize an industry's total profits, and non-cooperative lobbying, under which each firm acts to maximize its own profits. The free-riding parameter estimated by the herein analysis is different; it measures the level of organization associated with lobbying toward a public-good economic instrument—a price—be it cooperative or non-cooperative, in comparison to an assumed perfect non-cooperative lobbying for a private-good instrument—a firm's specific quota.

As aforesaid, our empirical application concerns the management of water allocation to Israeli agriculture.  Irrigation water accounts for 70% of the worlds' water extractions (Cornish et al. 2004), and 50% of the available fresh water from natural resources in Israel. The regulation of irrigation water is commonly managed by a combination of charges and quotas; e.g., in Australia, California, China, Iran, Israel, Peru and Spain. Frequently, quotas are binding, whereas charges are employed for partial recovering of pumping and delivery costs (Molle 2009). This is not the case in Israel, where since the mid-eighties the agricultural sector has utilized less water than allowed by the aggregated quotas (Kislev 2001); i.e., the prevailing equilibrium reflects real integrated regime. Furthermore, Zusman (1997), Kislev (2001), Mizrahi (2004) and Margoninsky (2006), present clear evidences for political influence on regulations in the Israeli market for agricultural water. Hence Israel makes an adequate case study for our empirical analysis.

The next section presents a political-economic model of a mixed-regime and heterogeneous users, and characterizes the conditions for political separating-equilibrium conditions. In Section III, these conditions are employed to form an empirical model, which is used for estimating water demand functions and the political parameters of the model. Section IV presents simulations of various control regimes.

## II. Theory

Consider a small open economy with a farming sector which is heterogeneous with respect to the production technology. We let $\alpha$ represent the farming unit technological level, and $Z(\alpha)$ be the corresponding distribution function. The profit per farm is given by $\pi(w,\alpha) - pw$, where $w$ is the farm's water consumption and $p$ is an administratively determined agricultural water price. The function $\pi(w,\alpha)$ subsumes the prices of all variable outputs and inputs, excluding $p$, and is assumed to be continuous, increasing, strictly concave and twice differentiable. The derivative of

$\pi(w,\alpha)$ with respect to the water consumption, *w*, is the water's value of marginal production (VMP): $\pi_w(w,\alpha)$. The inverse of this function $w=\pi_w^{-1}(p,\alpha)$, is the farm's water demand. As aforesaid, the industry is regulated by a mix of administrative price and quotas. The allocation of water quotas, *q*, among farms is represented by the distribution function $K(q)$. Given these notations, the farm's water consumption is given by $w=\min(\pi_w^{-1}(p,\alpha),q)$.

The price *p* and the distribution of quotas $K(q)$ constitute instruments used by an incumbent government to control water consumption. These controls are set through a political decision-making process, under which policies maybe bended by politicians in favor of interest-groups' lobbies that, in return, may provide political rewards. The policies constituting equilibrium in such a political system can be characterized as if they maximize the following governmental objective function, $G=(1-\gamma)S(p,K(q))+\gamma U(p,K(q))$, in which $S(p,K(q))$ and $U(p,K(q))$ are, respectively, the social welfare and the profits of the organized interest groups, and $\gamma$, $0\le\gamma\le 1$, is the weight attached by the politicians to political rewards. The micro foundations for this objective function are provided by Zusman (1976), Grossman and Helpman (1994), Finkelshtain and Kislev (1997), Damania and Fredriksson (2003), and others,

In line with the regulation practice prevailing in our case study—Israel—we consider a two-stage political game, where quotas are set subsequent the price determination. The political activity related to each stage varies. Lowering the price is the interest of the entire farming sector, and hence has a nature of public goods. Thus, it is expected that only a part of the sector will be involved in the political struggle for price cuts. On the other hand, free-riding with respect to persuasion of larger quotas is less probable, since quotas are farm-specific assets; however, only farms whose quota binds are expected to negotiate quota enlargements. The separation into two interest groups yields the political 'separating-equilibrium.'

We turn now to a formal characterization of the political equilibrium. Let $q^0$ denote a farming-unit's historical quota and $K^0(q^0)$ the associated distribution function. Define $\nu \equiv \pi_w(q^0, \alpha)$, $\nu \in [\nu^l, \nu^h]$ , as the water's value of marginal production (VMP) measured at the farming-unit's historical quota. The joint distribution of $Z(\alpha)$ and $K^0(q^0)$ form the distribution function $F(\nu)$ in the support $[\nu^l, \nu^h]$ . Given $p$ and $F(\nu)$, the water consumption of the farms with $\nu^l \le \nu \le p$ is dictated by the price, while those with $p < \nu \le \nu^h$ consume water quantities equal to their corresponding quotas. To facilitate the formal analysis we assume that $\nu$ can be used for representing the heterogeneity in the farming sector such that the function $\pi(w,\nu)$ is equivalent to $\pi(w,\alpha)$. Then, $w(p,\nu) = \pi_w^{-1}(p,\nu)$ if $\nu \in [\nu^l, p]$ , and $w = q(\nu)$ if $\nu \in (p, \nu^h]$ , where $q(\nu)$ is a quota-allocation function. Our interest is in the political equilibrium price $p^*$ and quota allocation rule $q^*(\nu)$.

*First Stage – Setting the Price*

The equilibrium price $p^*$ constitutes a solution to the problem

$$\max_p G(p) = \int_{\nu^l}^{p} \pi(w(p,\nu),\nu)F(\nu)d\nu + \int_{p}^{\nu^h} \pi(q(\nu),\nu)F(\nu)d\nu - cW(p, F(\nu))$$
$$+ \beta\phi\left\{\int_{\nu^l}^{p} [\pi(w(p,\nu),\nu) - pw(p,\nu)]F(\nu)d\nu + \int_{p}^{\nu^h} [\pi(q(\nu),\nu) - pq(\nu)]F(\nu)d\nu\right\}$$

where $W(p,F(\nu)) = \int_{\nu^l}^{p} w(p,\nu)F(\nu)d\nu + \int_{p}^{\nu^h} q(\nu)F(\nu)d\nu$ is the total water consumption,

$c$ is the per water-unit supplying cost, $\beta = \frac{\gamma}{1-\gamma}$ is the government's attitude toward political rewards relative to the social welfare, and $\phi$, $0 \le \phi \le 1$, represents the fraction of the rural sector which supports the lobby struggles for price reductions. Recalling that $\frac{\partial w(p,\nu)}{\partial p} = \frac{\partial q(\nu)}{\partial p} = 0$ for all $\nu \in (p, \nu^h]$ and $\pi_w(w(p,\nu),\nu) = p$ for all $\nu \in [\nu^l, p]$ , the FOC becomes:

$$\frac{\partial G}{\partial p} = (p-c)\int_{\nu^l}^{p} \frac{\partial w(p,\nu)}{\partial p} F(\nu)d\nu - \beta\phi W(p,F(\nu)) + \Delta(p) = 0 \qquad (1)$$

where $\Delta(p)$ is the change in *G* driven by an infinitesimal increase in the price through the change this increase makes in the water consumption of the farms exhibiting $\nu = p$. In equilibrium $\Delta(p) = 0$,[1] and since $\frac{\partial w(p,\nu)}{\partial p} \equiv \frac{1}{\pi_{ww}} < 0$ for all $\nu \in [\nu^l, p]$ , then, as long as $\beta\phi > 0$, there is $p^* < c$; i.e., the equilibrium price is lower than the marginal cost, entailing welfare loss.

*Second Stage – Allocating Quotas*

[1] $\Delta(p) = F(p)\begin{Bmatrix} \pi(w(p,p),p) - \pi(q^0(p),p) - c[w(p,p) - q^0(p)] \\ + \beta\phi[\pi(w(p,p),p) - pw(p,p) + \pi(q^0(p),p) - pq^0(p)] \end{Bmatrix}$ where $q^0(p)$ denotes the historical quota of farms having $\nu = p$. Let $\mu$ be an infinitesimal number. Under $p - \mu$, these farms consume their historical quotas, $q^0(p)$. When the price is increased by $\mu$, and becomes $p$, their water consumption is determined by the price such that $w(p,p) = \pi_w^{-1}(p,p)$. However, since there is $\nu = \pi_w(q^0(p),\alpha) = p$, we get $w(p,p) = q^0(p)$, which implies $\Delta(p) = 0$.

Given $p^*$ and $F(\nu)$, quotas are reallocated to farmers whose quotas are binding, that is having $\nu \in \left(p^*, \nu^h\right]$ . Since the sum of allotments affects the total water-supplying cost, the allocation under equilibrium is solved as a simple optimal control problem, where the cumulative water use $W(\nu) = \int_{\nu^l}^{p^*} w\left(p^*, \nu\right) F(\nu) d\nu + \int_{p^*}^{\nu} q(\nu) F(\nu) d\nu$ is the state variable, and $q(\nu)$ is the control. The objective is to

$$\max_{q(\nu)} G(q(\nu)) = \int_{p^*}^{\nu^h} \left[\pi(q(\nu), \nu)(1+\beta) - \beta p^* q(\nu)\right] F(\nu) d\nu - cW\left(\nu^h\right)$$

subject to $\dot{W}(\nu) = q(\nu) F(\nu)$. The resulted equilibrium rule with respect to $q(\nu)$ is:

$$\frac{c + \beta p^*}{1+\beta} = \pi_q\left(q^*(\nu), \nu\right)\Big|_{\nu \in \left(p^*, \nu^h\right]} \equiv \pi_q^* \qquad (2)$$

where $\pi_q^*$ is some positive constant. Thus, the political process yields an efficient intra-group water use equating the VMPs of all farms with $\nu \in \left(p^*, \nu^h\right]$ to $\pi_q^*$. Yet, as long as $\beta > 0$ , $\pi_q^* > p^*$, which implies inefficiency of water allocation between the price-controlled group and the group with binding quotas. Moreover, if $\beta > 0$ , then $c > \pi_q^*$, the water VMP is below the marginal cost, implying welfare loss.

*Comparative Statics*

The sequential procedure of political decision making implies that the impacts of changes in exogenous factors should be analyzed sequentially: the price is affected first, and its change affects the quotas allocation rule in the second stage. Table 1 summarizes the results. The influences of marginal shifts in the political parameters $\beta$ and $\phi$ on the price, and of the supplying cost *c*, are intuitive: the larger the power or representation of the farming sector in the political arena, the lower the price, whereas larger supplying costs enlarge the price due to the ensued welfare-loss increase. The impacts on the quotas are also expected: allotments are increased with $\beta$ and $\phi$, and shrink with $c$. Noteworthy is the indirect impact of $\phi$, which causes quotas enlargement through a price reduction.

Technological improvements and alternative schemes of historical allocations of quotas are modeled as changes in the $Z(\alpha)$ and $K^0(q^0)$ distribution functions—both cast on the $F(v)$ distribution. Assuming linear VMP, then, an upward first-order stochastic dominant shift of $Z(\alpha)$ leads to reduction in the price and augmentation of the quotas. On the other hand, the impact of a similar shift in the historical quotas $K^0(q^0)$ is indeterminate, since it entails additional welfare loss that may be offset by an increase in political pressures.

## III. Empirical Analysis

Israel is characterized by rainy winter seasons and dry summers. All the water sources in Israel are state property and therefore the government controls consumption by setting prices and allocating quotas once a year. Agricultural freshwater quotas are allocated specifically to each of the 860 rural villages, usually in the spring, before the irrigation season, at the time when information is available on the enrichment of the natural water storages during the winter. Prices are frequently set during the summer. Until 1989 the country was divided into 34 "water-price" regions in relation to the water delivery system; each was assigned a specific freshwater price. This regulation setup produced village-level data and aggregated regional-scale data that fit to the two separating equilibrium equations: the regional dataset is related to the price setting—Equation (1)—and the village level data are associated with the quotas allocation—Equation (2). These structural equations are used in our econometric estimation of technological and political factors.

### *Estimating the Demand Function and Quota Allocation Rule*

We commence with a village-level analysis, which is related to the second stage of the political game; i.e., quotas are allocated (in the spring) given the price set in the first stage (previous summer). Our objective is to estimate the political parameter $\gamma$ and village-level water-demand and political-equilibrium quota-allocation functions, while controlling for the heterogeneity among villages. To this end we make use of the methodology developed by Burtless and Hausman (1978) for the estimation of demand functions subject to piecewise-linear budget constraints. This method has been generalized by Mofitt (1986) and applied by Hewitt and Hanemann (1995) and Bar-Shira et al. (2006) for estimating, respectively, domestic and agricultural water-demand functions, utilizing the increasing block-rate water-pricing systems prevailed in California and Israel. Our analysis is based on a simplified block-rate pricing system, which involves only one block—each village is faced by one price and one quota. However, the quotas themselves are endogenous, since binding quotas are expected to be allocated according to the political equilibrium condition expressed by Equation (2). In the following we describe the empirical specifications and an estimation framework that incorporates this interdependency between the water demand and the allocation of quotas.

Let $\pi_{wit} = \vartheta_{it} + \psi w_{it}$ be the water's linear VMP function of village *i*, $i = 1,..., N$ , at year *t*, where $w_{it}$ and $\vartheta_{it}$ are the village-year specific water consumption and intercept, respectively, and $\psi$ is the slope, which is assumed identical for all *i* and *t*. The derived water demand function is $D(p_{it}, \mathbf{z}_{it}) = \boldsymbol{\mu}\mathbf{z}_{it} + \delta_1 p_{it}$, where $\mathbf{z}_{it}$ is a vector of village-year specific variables, $\boldsymbol{\mu}$ is the vector of corresponding coefficients, and $\delta_1 \equiv \psi^{-1}$. Let $q_{it}$ be the village annual water quota. By substituting into Equation (2) the linear VMP specification for the case of binding quota, $\pi_{wit}\big|_{w_{it}=q_{it}} = \vartheta_{it} + \psi q_{it}$, and rearranging, we get a linear political equilibrium quota allocation rule: $Q(p_{it}, \mathbf{x}_{it}) = \boldsymbol{\xi}\mathbf{x}_{it} + \delta_2 p_{it}$, where $\mathbf{x}_{it}$ is a vector of village-year specific variables, $\boldsymbol{\xi}$ is the associated coefficients vector and $\delta_2 \equiv \psi^{-1}\beta(1+\beta)^{-1}$. Using $\delta_1$ and $\delta_2$, the political parameter $\gamma$ is identifiable by $\gamma = \delta_2/\delta_2$.

Following the literature on piece-wise linear budget constraints, the heterogeneity across villages and along time that is unexplained by $p_{it}$ and $\mathbf{z}_{it}$ is represented by a random variable, denoted $\alpha_{it}$, which stands for managerial skills and other factors that are unobserved by the modeler, but known to the farmers, and therefore affect their water demands. Two additional sources of randomness are those associated with measurement and optimization mistakes that may emerge in both the farmer's decision on water usage and the allocation of quotas by the government—these are represented, respectively, by the error terms $\varepsilon_{it}$ and $u_{it}$. As in Hewitt and Hanemann (1995), Bar-Shira et al. (2006), and others, a linear additive formulation is adopted, which yields two interrelated equations of water demand and quota allocation:

$$w_{it} = \begin{cases} D(p_{it}, \mathbf{z}_{it}) + \alpha_{it} + \varepsilon_{it} & \text{if} \quad D(p_{it}, \mathbf{z}_{it}) + \alpha_{it} \le q_{it} \\ q_{it} + \varepsilon_{it} & \text{if} \quad D(p_{it}, \mathbf{z}_{it}) + \alpha_{it} > q_{it} \end{cases} \tag{3}$$

$$q_{it} = \begin{cases} q_{it-1} + u_{it} & \text{if} \quad D(p_{it}, \mathbf{z}_{it}) + \alpha_{it} \le q_{it-1} \\ Q(p_{it}, c_{it}, \mathbf{x}_{it}) + u_{it} & \text{if} \quad D(p_{it}, \mathbf{z}_{it}) + \alpha_{it} > q_{it-1} \end{cases} \tag{4}$$

Equation (3) states that as long as the water demand is smaller than the quota, the consumption equals the demand function $D(p_{it}, \mathbf{z}_{it}) + \alpha_{it}$, plus a stochastic term. If water demand exceeds the quota, then the observed water consumption equals the quota $q_{it}$ plus the stochastic error term. The quota itself is endogenous. This notion is treated by Equation (4), stating that if the historical quota exceeds the demand, and therefore is unbinding, then, $q_{it} = q_{it-1}$ plus an error term. An effective historical quota, on the other hand, would lead to a political bargaining that is expected to result in quota reallocation based on the political equilibrium quota function $Q(p_{it}, \mathbf{x}_{it})$.

We apply a maximum-likelihood estimation approach. Let $\Pr_{it}(w_{it}, q_{it} | p_{it}, q_{it-1}, \mathbf{z}_{it}, \mathbf{x}_{it}, \boldsymbol{\theta})$ be the probability of observing a pair of water consumption $w_{it}$ and quota $q_{it}$, where $\boldsymbol{\theta}$ is the set of parameters of the functions $D(p_{it}, \mathbf{z}_{it})$, $Q(p_{it}, \mathbf{x}_{it})$ and the joint density distribution functions of $\alpha$, $\varepsilon$ and $u$. This probability encompasses all the various combinations associated with the options in Equations (3) and (4). Define an indication variable $\tau_{it}$, where $\tau_{it} = 1$ if $q_{it} > q_{it-1}$ and $\tau_{it} = 0$ otherwise,[2] then

$$\begin{aligned}
&\Pr_{it}(w_{it}, q_{it} | p_{it}, q_{it-1}, \mathbf{z}_{it}, \mathbf{x}_{it}, \boldsymbol{\theta}) = \\
&\quad \Pr[\alpha_{it} + \varepsilon_{it} = w_{it} - D(p_{it}, \mathbf{z}_{it}), \alpha_{it} \le \min(q_{it}, q_{it-1}) - D(p_{it}, \mathbf{z}_{it}), u_{it} = q_{it} - q_{it-1}] \\
&+ \tau_{it} \Pr[\alpha_{it} + \varepsilon_{it} = w_{it} - D(p_{it}, \mathbf{z}_{it}), q_{it-1} < D(p_{it}, \mathbf{z}_{it}) + \alpha_{it} \le q_{it}, u_{it} = q_{it} - Q(p_{it}, \mathbf{x}_{it})] \\
&+ (1 - \tau_{it}) \Pr[\varepsilon_{it} = w_{it} - q_{it}, q_{it} < D(p_{it}, \mathbf{z}_{it}) + \alpha_{it} \le q_{it-1}, u_{it} = q_{it} - q_{it}] \\
&+ \Pr[\varepsilon_{it} = w_{it} - q_{it}, \alpha_{it} > \max(q_{it}, q_{it-1}) - D(p_{it}, \mathbf{z}_{it}), u_{it} = q_{it} - Q(p_{it}, \mathbf{x}_{it})]
\end{aligned} \tag{5}$$

and the resulted sample likelihood function is

$$L = \prod_i \prod_t \Pr_{it}(w_{it}, q_{it} | p_{it}, q_{it-1}, \mathbf{z}_{it}, \mathbf{x}_{it}, \boldsymbol{\theta}) \tag{6}$$

Assuming that the random variables $\alpha$, $e$ and $u$ are statistically independent and normally distributed, such that $\alpha \sim N(0, \sigma_\alpha^2)$, $\varepsilon \sim N(0, \sigma_\varepsilon^2)$ and $u \sim N(0, \sigma_u^2)$, the

[2] The relation between the observed pair of $q_{it}$ and $q_{it-1}$ implies some certainties. If $q_{it-1} > q_{it}$, and there is $D(p_{it}, z_{it}) + \alpha_{it} \le q_{it}$, then, the probability of $D(p_{it}, z_{it}) + \alpha_{it} \le q_{it-1}$ equals one, and that of the combination $q_{it-1} < D(p_{it}, z_{it}) + \alpha_{it} \le q_{it}$ is zeroed; otherwise, if $q_{it} > q_{it-1}$, and $D(p_{it}, z_{it}) + \alpha_{it} > q_{it}$, then, a probability of one for $D(p_{it}, z_{it}) + \alpha_{it} > q_{it-1}$ and zero for $q_{it} < D(p_{it}, z_{it}) + \alpha_{it} \le q_{it-1}$ are followed.

likelihood function in (6) is readily derivable in terms of the standard normal density, as described in Appendix.

*Estimating the Price Formation Equation*

For the regional scale analysis, let $N^l_{jt}$ be the number of region *j*'s price-effective observations at year *t*. Using our linear specification for the demand function, Equation (1) becomes:

$$p_{jt} = \boldsymbol{\zeta}\mathbf{c}_{jt} + \delta_3 W_{jt} \big/ N^l_{jt} + \eta_{jt} \tag{7}$$

where $\mathbf{c}_{jt}$ is a vector of regional level supplying-cost related variables, $\boldsymbol{\zeta}$ is the set of corresponding coefficients, $W_{jt}$ is the region's total water consumption at year *t*, $\eta_{jt}$ is an error term and $\delta_3 \equiv \psi\beta\phi$ is the coefficient of interest. Thus, using the results from the village level analysis we get $\phi = \delta_3\delta_1(\delta_1 - \delta_2)/\delta_2$ . Note that the ratio $W_{jt}\left(N^l_{jt}\right)^{-1}$ is endogenous, and therefore estimation requires applying an instrumental-variables regression.

*Estimation Results*

The estimation is based on a panel of 1,093 observations along the years 1985-88, encompassing 303 villages that are spread over 23 water-price regions. These observations, which account for 20% of the agricultural freshwater consumption in Israel, were selected according to three criteria: (a) villages that have access to brackish or treated wastewater were omitted to avoid potential misrepresentation of the VMP by the freshwater price; (b) to prevent uncertainty with respect to the price, we include villages that have access only to freshwater delivered by Mecorot—the public company, which supplies 60% of the water nationwide; (c) to ensure momentous agricultural activity we exclude villages with cultivated area or water quota lower than 50ha and 50,000 $m^3$/year, respectively.

Table 2 provides descriptive statistics of the variables in the dataset and their sources. There are two remarkable points. First, the existence of separating equilibrium during the relevant period is evident by the fact that in 53% of the observations water quota exceeds consumption. Second, delivery cost was computed for each village based on the national water-delivery system pertinent to 1987. Detailed engineering and economic information enabled separation of the energy-delivery costs from the total delivery costs, which include the additional capital and operational expenses (all monetary values are in terms of 1987 US dollars). Figure 1 presents the regional weighted average costs and prices in each of the 23 regions. The comparison gives a clue on prospective successful lobbying for low agricultural prices: in 17 regions both the total- and energy delivery costs are higher than the price, in 5 regions the price lays between the two cost measures, and in only one region the price surpasses the total costs. Also presented in Figure 1 are the nationwide consumption-weighted average price and costs, as well as the average costs calculated by Tahal L.T.D. (1988) in an official governmental report. The latter encompasses underestimates of capital costs and therefore is comparable to our average energy-costs calculation, which is 1.6 cents per $m^3$ higher.

The estimation results are summarized in Table 3. Figure 2 provides information on the goodness-of-fit of the expected values of the water consumption, $E(w)$, and the water quota, $E(q)$, as calculated by the use of the probability function in Equation (5), to their observed counterparts.

The village-level estimates are shown in the upper section of Table 3. Regarding the water demand, the estimated values of $\sigma_\alpha$ and $\sigma_\varepsilon$ indicate that 60% of the variation of water consumption unexplained by the variables is associated with the heterogeneity among villages. As expected, the price coefficient ($\delta_1$) is negative and significant, with a calculated elasticity of 0.84. This estimate rests above the 0.30-0.59 range of elasticities reported by Bar-Shira et al. (2006) for the period 1992-1997—an expected outcome given the lower consumption in the latter. While the rainfall variables do not exhibit statistically significant impacts, higher elevation above sea level, which is associated with lower temperatures, reduces consumption. Unsurprisingly, villages located in the semi-arid southern part of Israel and those with larger perennials acreage consume larger irrigation quantities.

Compared to the demand function, the quota-allocation function is more involved. While the goodness-of-fit is better (see Figure 2), and almost all the coefficients are statistically significant, the interpretation of the impacts these coefficients represent is less trivial. This is due to the presence of three sources of uncertainty with respect to the political process associated with the quota allocation. The first is the delivery costs—was the government aware of the costs we have calculated? Our average energy costs are quite similar to those reported to the government (Tahal L.T.D. 2008), albeit, a major concern in semi-arid countries like Israel is water scarcity, which is not reflected by the delivery costs. The nationwide natural enrichment of water storages is included in an attempt to capture this effect. Note that the elevation above sea level was omitted from the quotas-equation because of its correlation with the delivery costs. Rainfall in October was also excluded, since it is unknown at the spring time, when quotas are allocated. The second source of uncertainty is related to the information available to the government on the VMP of the various water users. Recalling Equation (2), the government allocates quotas in relation to the consumers' VMPs as they are measured at the quotas of the consumers whose quotas are binding. While the set of explanatory variables herein used for estimating the demand function were available to the government, perhaps the handiest indicator of a village's VMP is its previous-year quota, which is therefore inserted to this set. The third uncertain factor is the non-uniformity of political influence across agents in the agricultural sector. The parameter $\gamma$ represents the extent to which policies can be bended in favor of interest groups as a result of the willingness of the government to do so, as well as a consequence of the pressure put on the politicians by lobbies. The agricultural sector may be heterogeneous with respect to both factors. Thus, while our estimation yields the rural-sector's average value of $\gamma$, the heterogeneity among villages can emerge in relation to the various influential factors represented by the set of explanatory variables. The discussion proceeds with these notions in mind.

The coefficient of the price ($\delta_2$) is negative. In view of Equation (2), this result supports the model's hypothesis: a higher price entails higher value of $\pi_q^*$, which, given the negativity of the price effect on the water demand ($\delta_1$) implies lower quotas. The capital and operational costs serve as indicators of the installed infrastructure of the water-delivery system, and therefore, as expected, villages associated with larger transference capacity obtain larger allotments. The negativity of the energy-costs coefficient is in line with the theory—higher delivery costs increase welfare loss, and thereby induce politicians to reduce the quotas devoted to agriculture. This effect is enlarged when water becomes less abundant, as can be learned from the positivity of the natural-enrichment coefficient. Given our sample's average per-village annual quota, and the $1.3\times10^9$ $m^3$ nationwide cumulative quotas (Kislev and Vaksin, 2003), from a back-of-the-envelop calculation we get that a reduction of one $m^3$ of water in an annual national enrichment entails a cut of nearly 0.15 $m^3$ in the aggregated quotas. The statistical significance of the enrichment coefficient indicates that water scarcity is, indeed, an influential factor.

The previous-year quota constitutes a significant factor in quota distribution, explaining about 75% of every allotted $m^3$ of water. As noted, the coefficients of the rest of the explanatory variables might represent the integrated influence of additional supplying-costs factors, political-power heterogeneity and water's VMP variation. For example, villages with larger rainfall in April—the beginning of the irrigation season—are expected to face lower VMP of irrigation water, and therefore may devote lower efforts in the persuasion for larger quotas. The opposite may happen in response to improvement in the terms-of-trade. A prospective indication of political heterogeneity among sectors are the smaller quotas allotted to villages populated by minorities. Delegators of such villages may find lower access to policy makers. However, another interpretation of this finding may be attributed to variation in enforcement patterns—minorities appear to have the highest level of water use in excess of their quotas (Kislev and Vaksin, 2003); this incompliance habits may render negotiations of quotas enlargements redundant.

Using the delta method (Green, 2003), the value of the $\gamma$ parameter is estimated to be 0.52, where the equality to both zero and one is rejected in the 5% confidence. The validity of these values is reinforced by the findings of Zusman and Amiad (1977), who estimated $\gamma$ to lay within the range of 0.4-0.6 for the Israeli Diary and Sugar industries during the early seventies. These estimates are considerably higher than those obtained by the aforedescribed series of studies on international trade barriers (Gawande and Magee, 2010).

The results of the regional scale regression are shown in the lower part of Table 3. There are 72 region-year observations, which, in order to account for size differences, were weighted by their corresponding number of villages; though, the results obtained by a non-weighted analysis (not shown) are akin. The price in regions with higher capital and operational costs is higher, whereas energy costs do not exhibit significant impact. The $\delta_3$ ($=\psi\beta\phi$) coefficient is negative and statistically significant, indicating that a hypothesis of no political pressure is rejected, although the lobbying participation rate $\phi$, as calculated by the Delta method to be 0.22, is not statistically different than zero. On the other hand, we could reject the corner solution of $\phi=1$, which points on the presence of free-riding in lobbying with respect to the water price, in comparison to the assumed full participation regarding the quotas allocation.

**IV. Simulations**

We are now in a position to compare among the observed separating equilibrium and the alternative mono-control regimes that lead to the pooling-price and pooling-quotas equilibria. In view of Equation (1), and given our empirical specifications, the price under the pooling-price equilibrium becomes $p_{it}^* = \dfrac{\bar{c}_{jt} - \beta\phi\bar{\vartheta}_{jt}}{1-\beta\phi}$, where $\bar{\vartheta}_{jt}$ is the regional average estimated intercept of the linear VMP function. The pooling-quotas equilibrium is considered as the one obtained by substituting $p_i = 0$ in the estimated functions $D(p_{it}, \mathbf{z}_{it})$ and $Q(p_{it}, \mathbf{x}_{it})$ for all $i = 1,\dots,N$. The VMP measured at the quota is given by $\pi_{q\,it}^* = \vartheta_{it} + \psi Q(0, \mathbf{x}_{it})$, so that the welfare loss (consumer distortion triangles) can be calculated by $WL_{it} = \frac{1}{2}\text{cotangent}(\psi)(c_{it} - \pi_{w\,it}^*)^2$, where $\pi_{w\,it}^* = \max(p_{it}^*, \pi_{q\,it}^*)$ and $c_{it}$ is taken as the total delivery costs. Ranking the regimes is based on the welfare-loss expectations, calculated by the probability function in Equation (5).

The results are reported in Table 4 in terms of expected values per average village. The price under the pooling-price regime is doubled relative to the observed one, whereas the VMP under the pooling-quotas equilibrium is five times lower.

Consequently, the pooling-price policy is the favorite, while the pooling-quotas regime is the worst: the welfare loss under this policy is lower by 17% and 45% relative to the observed mixed regime and the simulated pooling-quotas equilibrium, respectively. Moreover, this rank is found to be robust to changes in the organization rate—simulating perfect organization in the two-stage separating equilibrium reveals converges into the pooling-quotas equilibrium; hence, prices remain favorable even under the extreme case of $\phi = 1$, as shown in the last column in Table 4.

Our last task is to examine whether the water-price hike and quotas cut occurred in Israel after the mid eighties indicate a reduction in the agriculture-related political factors $\beta$ and/or $\phi$. The terms-of-trade of the agricultural branch have diminished by 30% during the period 1987-2002. Using our model for simulating the effect of such a reduction yields changes in the fresh-water's price, quotas and consumption which are almost similar to the observed ones (Table 5). Thus, the reduction in the profitability of agriculture, which in turn reduces both the welfare generated by the water devoted to the agricultural sector and the incentive of its members to implement political pressure, can provide a rather good explanation to the observed trends.

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## Appendix

Let $\varphi = \alpha + \varepsilon$ and let $g_{\varphi\alpha}(\varphi, \alpha)$ denote the joint density of $\varphi$ and $\varepsilon$, where the density $g_{\varphi\alpha}$ is bivariate normal with parameters $\sigma_\varphi^2 = \sigma_\alpha^2 + \sigma_\varepsilon^2$, $\sigma_\alpha^2$ and $\rho = \frac{Cov(\alpha, \alpha+\varepsilon)}{\sigma_\varphi \sigma_\alpha} = \frac{\sigma_\alpha^2}{\sqrt{(\sigma_\alpha^2 + \sigma_\varepsilon^2)\sigma_\alpha^2}} = \frac{\sigma_\alpha}{\sigma_\varphi}$. In the same manner, $g_{\varphi\alpha u}$ and $g_{\alpha\varepsilon u}$ are the joint densities of $\varphi$, $\alpha$ and $u$ and $\alpha$, $\varepsilon$ and $u$, respectively. The distribution of $\alpha$ conditional on $\varphi$ implies $g_{\varphi\alpha}(\varphi, \alpha) = g_{\alpha|\varphi}(\alpha|\varphi) g_\varphi(\varphi)$, and due to the independence of $\alpha$, $\varepsilon$ and $u$ there is $g_{\varphi\alpha u} = g_{\alpha|\varphi} g_\varphi g_u$ and $g_{\alpha\varepsilon u} = g_\alpha g_\varepsilon g_u$. Omitting unessential indices and functions' operators, the probability of observing a certain pair of $w$ and $q_t$ can be expressed in terms of $g$:

$$
\begin{aligned}
&L(w, q_t, \mathbf{\theta}) = \\
&g_\varphi(w-D) g_u(q_t - q_{t-1}) \int_{-\infty}^{\min(\hat{\alpha}^t, \hat{\alpha}^{t-1})} g_{\alpha|\varphi}(\alpha) d\alpha \;+\; \tau\, g_\varphi(w-D) g_u(q_t - Q) \int_{\hat{\alpha}^{t-1}}^{\hat{\alpha}^t} g_{\alpha|\varphi}(\alpha) d\alpha \;+ \\
&(1-\tau) g_\varepsilon(w - q_t) g_u(q_t - q_{t-1}) \int_{\hat{\alpha}^t}^{\hat{\alpha}^{t-1}} g_\alpha(\alpha) d\alpha \;+\; g_\varepsilon(w - q_t) g_u(q_t - Q) \int_{\max(\hat{\alpha}^t, \hat{\alpha}^{t-1})}^{\infty} g_\alpha(\alpha) d\alpha
\end{aligned}
$$

where $\hat{\alpha}^t = q_t - D$ and $\hat{\alpha}^{t-1} = q_{t-1} - D$. The distribution $g_{\varphi\alpha}$ is bivariate normal, hence $g_{\alpha|\varphi}(\alpha|\varphi)$ is distributed $N(\rho^2\varphi, \sigma_\alpha^2(1-\rho^2))$. Using $f$ and $F$ to denote the density and the cumulative distribution functions of a standard normal random variable, respectively, the probability function can be written:

$$
\begin{aligned}
&L(w, q_t, \mathbf{\theta}) = \\
&\frac{1}{\sigma_\varphi} f(h) \frac{1}{\sigma_u} f(o) F(\min(r^t, r^{t-1})) + \tau \frac{1}{\sigma_\varphi} f(h) \frac{1}{\sigma_u} f(y) [F(r^t) - F(r^{t-1})] + \\
&(1\text{-}\tau) \frac{1}{\sigma_\varepsilon} f(s) \frac{1}{\sigma_u} f(o) [F(k^{t-1}) - F(k^t)] + \frac{1}{\sigma_\varepsilon} f(s) \frac{1}{\sigma_u} f(y) [1 - F(\max(k^t, k^{t-1}))]
\end{aligned}
$$

where $o = \frac{q_t - q_{t-1}}{\sigma_u}$, $h = \frac{w - D}{\sigma_\varphi}$, $r^t = \frac{\hat{\alpha}^t - \rho^2(w - D)}{\sigma_\alpha \sqrt{1 - \rho^2}}$, $r^{t-1} = \frac{\hat{\alpha}^{t-1} - \rho^2(w - D)}{\sigma_\alpha \sqrt{1 - \rho^2}}$,

$y = \frac{q_t - Q}{\sigma_u}$, $s = \frac{w - q_t}{\sigma_\varepsilon}$, $k^t = \frac{\hat{\alpha}^t}{\sigma_\alpha}$ and $k^{t-1} = \frac{\hat{\alpha}^{t-1}}{\sigma_\alpha}$.

Table 1 – Comparative statics of separating equilibrium.

| Parameter | Impact on $p^*$ | Impact on $q^*(\nu)$ |
| --- | --- | --- |
| $\beta$ | - | + |
| $\phi$ | - | + |
| $c$ | + | - |
| $Z(\alpha)$[a] | - | + |
| $K^0(q^0)$[a] | ? | ? |

a. Analyzed based on a linear water's VMP function.

Table 2 – Description of variables.

| **Variable** | **Spatial unit** | **Units** | **Mean / Frequency** | **Std. Dev.** |
|---|---|---|---|---|
| Freshwater use[a] | Village | [ $10^3 \times m^3$ $year^{-1}$ ] | 933 | 488 |
| Freshwater quota[a] | Village | [ $10^3 \times m^3$ $year^{-1}$ ] | 1,012 | 429 |
| Freshwater price[b] | Region | [ $ $(m^3)^{-1}$ ] | 0.11 | 0.02 |
| Energy delivery costs[c] | Village | [ $ $(m^3)^{-1}$ ] | 0.23 | 0.10 |
| Capital & operation costs[c] | Village | [ $ $(m^3)^{-1}$ ] | 0.14 | 0.08 |
| Natural enrichment[a] | Nationwide | [ $10^6 \times m^3$ $year^{-1}$ ] | 1,280 | 313 |
| October rainfall[d] | Village | [ mm $month^{-1}$ ] | 35.9 | 26.2 |
| April rainfall[d] | Village | [ mm $month^{-1}$ ] | 22.3 | 22.5 |
| Annual rainfall[d] | Village | [ mm $year^{-1}$ ] | 526 | 183 |
| Elevation above sea level[b] | Village | [ m ] | 183 | 223 |
| Agricultural land[b] | Village | [ $10^3 \times m^2$ ] | 2,745 | 2,201 |
| Perennials area[b] | Village | [ $10^3 \times m^2$ ] | 738 | 578 |
| Terms of trade[e] | Nationwide | Index (1952=100) | 65.2 | 1.30 |
| Light soil[f] | Village | Dummy | 2% | - |
| Medium-light soil[f] | Village | Dummy | 44% | - |
| Heavy-medium soil[f] | Village | Dummy | 6% | - |
| Heavy soil[f] | Village | Dummy | 48% | - |
| North[b] | Village | Dummy | 37% | - |
| Center[b] | Village | Dummy | 43% | - |
| South[b] | Village | Dummy | 20% | - |
| Minorities[b] | Village | Dummy | 4% | - |
| Semi-cooperative (*Moshavim*) [b] | Village | Dummy | 75% | - |
| Cooperative (*Kibutzim*) [b] | Village | Dummy | 21% | - |

a. Enrichment of natural storages in the previous year as calculated by the Israeli Water Commission.

b. Obtained from the Ministry of Agriculture and Rural Development.

c. Calculated using data obtained from Engineer Gabriel Shaham (Tahal Ltd.).

d. Obtained from the Israeli Meteorological Service.

e. From Kislev and Vaksin (2003).

f. Based on Ravikovitch (1992).

| | | |
|---|---|---|
| **Demand Function and Quota Allocation Rule** | | |
| Observations | 1,093 | |
| Wald $\chi^2(15)$ | 129.4 | |
| $\sigma_\alpha$ | 405** | |
| $\sigma_\varepsilon$ | 243** | |
| $\sigma_u$ | 145** | |
| | Demand ($D$) | Quota ($Q$) |
| Price | -7,185** ($\delta_1$) | -3,761** ($\delta_2$) |
| Energy costs | - | -337.6** |
| Capital & operation costs | - | 229.8** |
| Natural enrichment | - | 0.106** |
| $q_{t-1}$ | - | 0.756** |
| Elevation above sea | -0.643** | - |
| October rainfall | -0.394 | - |
| April rainfall | -0.356 | -2.857** |
| Annual rainfall | -0.221 | 0.020 |
| Agricultural land | 0.023 | 0.015** |
| Perennials area | 0.330** | 0.061** |
| Light soil | -16.22 | 129.1** |
| Medium-light soil | 23.87 | -28.49** |
| Heavy-medium soil | 3,165 | 142.6** |
| Terms of trade | 30.28 | 29.45** |
| Center | 66.05 | 57.13** |
| South | 382.6** | -31.98 |
| Minorities | 302.1 | -224.1** |
| Semi-cooperative | -81.89 | 8.34 |
| Constant | 74.40 | -1,427** |
| Demand elasticity | 0.84 | |
| $\gamma = \delta_2 / \delta_1$ | 0.52** (95% Conf.: 0.05 to 0.99) | |
| **Price Formation Equation** | | |
| Observations | 1,039 | |
| Wald $\chi^2(8)$ | 113.6 | |
| $W/N^l$ (instrumented)[a] | $-3.43\times10^{-5}$** ($\delta_3$) | |
| Energy costs | $-3.94\times10^{-3}$ | |
| Capital & operation costs | $1.03\times10^{-2}$** | |
| Natural enrichment | $-5.88\times10^{-5}$ | |
| Constant | 0.187** | |
| $\phi = \delta_3\delta_1(\delta_1 - \delta_2)/\delta_2$ | 0.22 (95% Conf.: -0.37 to 0.82) | |

* = significant at 10%, ** = significant at 5%

a. Instruments include the rainfall during October and April, elevation above sea level and dummies for years and location in the central and southern areas of the country.

Table 4 – Comparison of simulated control regimes (per average-village values).

| | **Separating (observed)** | **Pooling Quotas** | **Pooling Price** | **Pooling Price ($\phi = 1$)** |
|---|---|---|---|---|
| Average cost ($/m$^3$) | 0.36 | 0.36 | 0.37 | 0.37 |
| Average price ($/m$^3$) | 0.11 | - | 0.22 | 0.12 |
| $E(\pi_q)$ ($/m$^3$) | 0.21 | 0.02 | - | - |
| $E(w)$ ($10^3$ m$^3$/year-village) | 986 | 1,409 | 867 | 1,601 |
| $E(q)$ ($10^3$ m$^3$/year-village) | 1,069 | 1,413 | - | - |
| $E(WL)$ ($10^3$ $/year-village) | 137 | 357 | 84 | 255 |
| $E(WL)/E(w)$ ($/m$^3$) | 0.14 | 0.25 | 0.10 | 0.16 |

Table 5 – Percentage changes in fresh-water's price, aggregated consumptions and quotas, as occurred from 1987 to 2002, in comparison to simulated results of a 30% reduction in the agriculture's terms of trade, as observed during that period.

| | **Observed changes** | **Simulated 30% reduction in TOT** |
|---|---|---|
| Price | +32 | +27 |
| Quotas | -18 | -14 |
| Consumption | -47 | -50 |

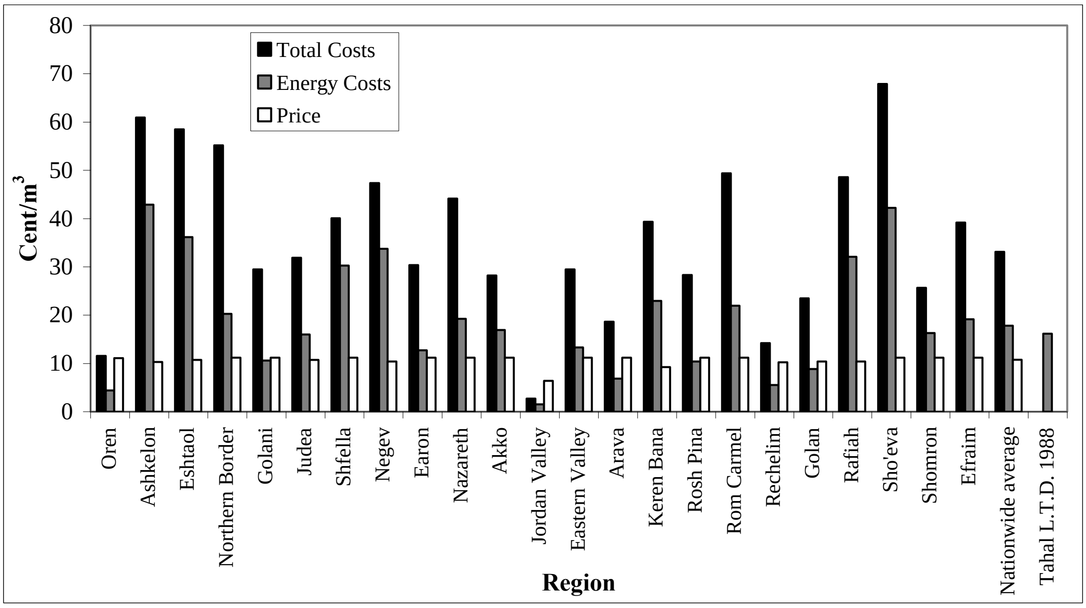
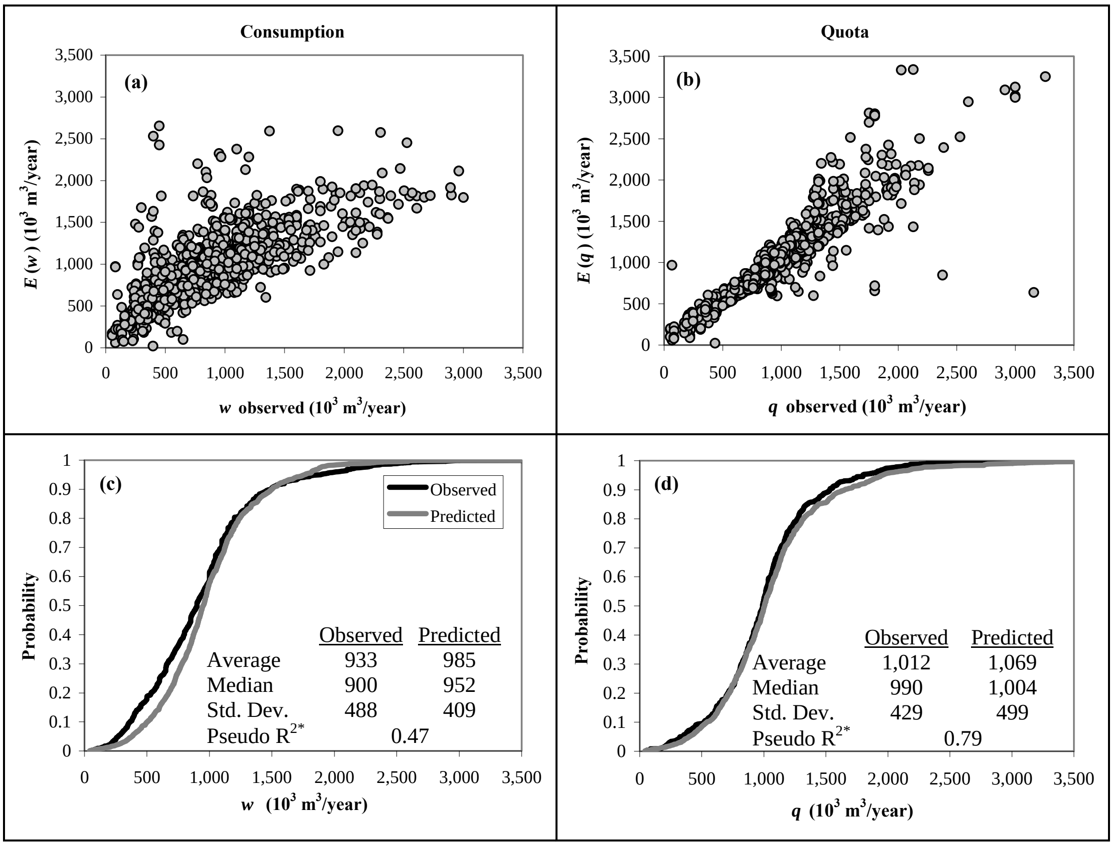



Figure 1 – Regional weighted average costs and prices.




* Pseudo $R^2$ refers here to the square of the correlation between predicted and observed values.

Figure 2 – Predicted versus actual distributions of water consumption ((a) and (c)) and quota ((b) and (d)) under the energy-costs model.

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