Regulation under Asymmetric Information in Water Utilities

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Water utilities are reminiscent of network industries and are characterized by important fixed costs. These factors contribute to a single firm serving an area justifying public intervention on pricing. About one-fourth of U.S. water utilities are private and subject to regulation. Regulators are unlikely to be perfectly informed and regulation is unlikely to be costlessly implemented. These inherent imperfections have led economists to consider the incentive properties of regulatory procedures using the economics of information (see David Baron, 1989). The empirical literature on regulation has focused on evaluating the effects of regulation on prices, firms' costs, efficiency, and innovation in such sectors as airlines, electricity, and energy, as surveyed by Paul L. Joskow and Nancy L. Rose (1989). Few of these empirical studies rely on the so-called theory of regulation. Regarding the water industry, there is an abundant literature on residential water demand, firms' cost, and their efficiency, given their public-versus-private nature. Relying on a model with asymmetric information and a sample of California water utilities, Frank A. Wolak (1994) assesses the consumer welfare loss due to asymmetric information and shows that the model with asymmetric information provides a superior description of the cost and demand data to the model under perfect information. Analyzing pricing for residential water is an important policy issue as the sector recently experienced price increases. The problem is even more acute in California because of a high residential demand for water along with population growth, water scarcity, and the probability of severe droughts.

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Relying on a new dataset of 32 districts in California over the 1995–2000 period, we analyze regulation of private water utilities. For every district, the California Public Utilities Commission (CPUC) chooses a price for water, an access fee per meter, and a rate of return on capital to satisfy firms' revenue requirements. We assume that the CPUC is imperfectly informed about firms' labor efficiency. Following David Besanko (1984) and Wolak (1994), we develop a model in which the firm's capital is used as a screening variable. In particular, the model has the features of a rate-of-return regulation. We show how the rate of return and the access fee can be determined optimally to control firms' rents. We then adopt a structural approach to analyze the data. A multistep estimator allows us to estimate the key parameters of the model. The empirical results show price inelasticity, an income effect, slightly decreasing returns to scale, and a concentration of efficient firms. The computation of the optimal rate of return and access fee shows that the CPUC would tend to be cautious by allowing a lower-than-optimal rate and access fee. Relying on the estimated parameters, a first experiment evaluates the cost of asymmetric information. The price would be significantly lower, resulting in a gain of consumer surplus. A second experiment consists of simulating the outcome of an optimal price cap following the Farid Gasmi et al. (2002) model. The price cap became a popular regulatory tool in the 1980s such as for electricity, though the incentives resulting in price cap regulation have been questioned by economists. The counterfactual simulations show a price increase, which results in a significant loss in consumer surplus. The increase in firms' profit does not, however, counterbalance this loss supporting the relevance of the actual rate-of-return mechanism.

I. Data

Class A utilities serve more than 10,000 residential connections and are required to submit annual reports on their capital stock including

TABLE 1—SUMMARY STATISTICS

Variable	Mean	STD
Population	68,635.87	76,712.70
Income per capita	19,216.99	7,589.44
Rainfall (in inches)	40.00	23.80
Water delivered (in hundred cubic feet)	5,073,353.52	5,629,467.36
Water price	1.17	0.62
Meter price	9.88	5.24
Capital stock	22,401,770.35	21,957,186.28
Footage of pipeline	1,111,151.71	1,068,542.94
Variable cost	5,548,544.59	6,952,976.35
Labor price	25,472.15	11,922.65
Energy price	0.51	0.35
Capital price	0.09	0.006
Rate of return	0.10	0.006

water sources and operating costs. The rate cases provide information on water price, meter price or access fee, rate of return, and the interest rate on investment paid by the utility (see Wolak, 1994, for the regulatory process used by the CPUC). The CPUC is in charge of protecting consumers' interests by challenging any claim made by utilities through the general rate cases. The CPUC also exercises some control over the utility's capital stock. The important role played by the capital suggests that the regulator uses the utility's capital stock as a screening variable in the spirit of the Besanko (1984) model. There is an important heterogeneity in the quality of labor across the districts. It is expected that the utilities are better informed about the labor quality than the regulator. Annual reports do not provide complete information on labor costs. Out of the 58 districts regulated by the CPUC, 32 are served by the California Water Service Company and the Southern California Water Company. We focus on these 32 districts from 1995 to 2000, and make a total of 192 observations. Data on income per capita and rainfall were collected from the Bureau of Economic Analysis, Department of Commerce, and the Water Resources of California, respectively. All monetary variables are expressed in 1995 dollars. Table 1 provides summary statistics on the key variables. The data present an important variability over districts. A hedonic price model shows that the price of water tends to be higher in Southern California and rural areas than it is in Northern California and urban areas. The former can be explained by the scarcity of water sources, while the latter is due to additional capital in pipelines. A comparison of capital stock with variable cost shows a large capital requirement. Energy expenses represent an important proportion of operating costs because of water pumping. The energy price is measured as the ratio of the energy expenses per foot of pipe. The rate of return, which varies from 0.089 and 0.113, is always higher than the price of capital, which varies from 0.079 to 0.103. Districts have applied for rate cases on average 5.47 times, i.e., almost once a year, suggesting frequent revisions of prices and rates of return by the CPUC.

II. The Model and Econometric Modeling

We consider a model in the spirit of Baron and Roger B. Myerson (1982) and Besanko (1984). The plant is privately informed about its labor efficiency or type θ distributed as $F(\cdot)$ on $[\underline{\theta}, \bar{\theta}]$, where $\underline{\theta}$ ($\bar{\theta}$) denotes the most (least) efficient plant. The plant chooses a level of capital, K, that is observable and can be contracted upon. Investing K costs δK. The cost is $C(\theta, K, q, \varepsilon_c)$, where q is the quantity demanded by consumers and ε_c is a stochastic shock. It is increasing in θ and q and decreasing in K. The demand $q(p, \varepsilon_d)$ is subject to a stochastic shock ε_d. The regulator offers a scheme $[p(K), T(K), R(K)]$ where $p(K)$ is the price per unit, $T(K)$ is the total access fee, and $R(K)$ is the rate of return on capital. Then, the plant's expected payoff is $U = p(K)E[q(p(K), \varepsilon_d)] - E[C(\theta, K, q(p(K), \varepsilon_d), \varepsilon_c)] - \delta K + T(K)$, where $E(\cdot)$ denotes expectations with respect to ε_d and ε_c. The rate of return satisfies the revenue requirement $Ep(K)[q(p(K), \varepsilon_d)] - E[C(\theta, K, q(p(K), \varepsilon_d), \varepsilon_c)] + T(K) = R(K)K$. Given the scheme, a plant with type θ chooses a level of capital $K(\theta)$ and in equilibrium, it is allowed to charge $p(K(\theta)) \equiv p(\theta)$ and $T(K(\theta)) \equiv T(\theta)$ and is entitled to $R(K(\theta)) \equiv R(\theta)$. Because the CPUC protects consumers' interests, the regulator's objective is to maximize consumers' surplus while satisfying the revenue requirement and anticipating the plant's strategic response.

PROPOSITION 1: *The rate-of-return regulation yields $K^*(\theta)$, $p^*(\theta)$, $T^*(\theta)$, and $R^*(\theta)$ satisfying*

$$p^*(\theta)\, E[q_p(p^*(\theta),\, \varepsilon_d]$$
$$= E[C_q(\theta,\, K^*(\theta),\, q(p^*(\theta),\, \varepsilon_d),\, \varepsilon_c)$$
$$\times\, q_p(p^*(\theta),\, \varepsilon_d)]$$
$$+\, E[C_{\theta q}(\theta,\, K^*(\theta),\, q(p^*(\theta),\, \varepsilon_d),\, \varepsilon_c)$$
$$\times\, q_p(p^*(\theta),\, \varepsilon_D)]\, \frac{F(\theta)}{f(\theta)},$$

$$\delta = -E[C_K(\theta,\, K^*(\theta),\, q(p^*(\theta),\, \varepsilon_d),\, \varepsilon_c)]$$
$$-\, E[C_{\theta K}(\theta,\, K^*(\theta),\, q(p^*(\theta),\, \varepsilon_d),\, \varepsilon_c)]$$
$$\times\, \frac{F(\theta)}{f(\theta)},$$

$$T^*(\theta) = -E[q(p^*(\theta),\, \varepsilon_d)]p^*(\theta))$$
$$+\, E[C(\theta,\, K^*(\theta),\, q(p^*(\theta),\, \varepsilon_d),\, \varepsilon_c)]$$
$$+\, R^*(\theta)K^*(\theta),$$

$$R^*(\theta)K^*(\theta) = \delta K^*(\theta)$$
$$+ \int_{\theta}^{\hat{\theta}} E[C_\theta(s,\, K^*(s),\, q(p^*(s),\, \varepsilon_d),\, \varepsilon_c)]\, ds$$
$$+\, [R^*(\bar{\theta}) - \delta]K^*(\bar{\theta})$$

where $R^*(\bar{\theta})$ is a constant left to the discretion of the regulator.[1]

In the presence of asymmetric information, the regulator must grant rents to induce the plant to make optimal decisions. The revenue requirement can be rewritten as $U = [R(\theta) - \delta]K(\theta)$, and therefore the rate of return determines by which amount total revenues must exceed cost, and guarantees each plant is provided correct incentives. Overall, the rate-of-return regulation is the optimal second-best policy. Note, however, that the policy does not include a nonnegative profit requirement and the regulator can choose arbitrarily $R^*(\bar{\theta})$, so that the least efficient plants may make losses.

We also consider the price cap regulation as in Gasmi et al. (2002), given its popularity over the past 20 years. In that case, the regulator sets a price cap $\bar{p}$ and the plant is free to choose K as well as any price below $\bar{p}$. In the optimal price cap, the most efficient plants charge their monopoly prices and only less efficient plants are constrained by the cap.

PROPOSITION 2: *In the pure price cap regulation,*

(*a*) *There exists $\hat{\theta}$ such that $\forall\ \theta < \hat{\theta}$, the plant charges $p^M(\theta)$ and invests $K^M(\theta)$ where*

$$p^M(\theta)\, E[q_p(p^M(\theta),\, \varepsilon_d)]$$
$$+\, E[q(p^M(\theta),\, \varepsilon_d)]$$
$$= E[C_q(\theta,\, K^M(\theta),\, q(p^M(\theta),\, \varepsilon_d),\, \varepsilon_c)$$
$$q_p(p^M(\theta),\, \varepsilon_d)]$$
$$\delta = -E[C_K(\theta,\, K^M(\theta),\, q(p^M(\theta),\, \varepsilon_d),\, \varepsilon_c)]$$

and $\forall\ \underline{\theta} \geq \hat{\theta}$, the plant charges $\bar{p}$ and invests $\bar{K}(\theta, \bar{p})$ where $\delta = -E[C_K(\theta, \bar{K}(\theta, \bar{p}), q(\bar{p}, \varepsilon_d), \varepsilon_c)]$,

(*b*) *$\bar{p}$ is such that $E[q(\bar{p}, \underline{\varepsilon_d})]\bar{p} - E[C(\bar{\theta}, \bar{K}(\bar{\theta}, \bar{p}), q(\bar{p}, \varepsilon_d), \varepsilon_c)] - \delta\bar{K}(\bar{\theta}, \bar{p}) = 0$,*

(*c*) *$\hat{\theta}$ is such that $p^M(\hat{\theta}) = \bar{p}$.*

We adopt a structural approach to estimate the model, i.e., the econometric model is directly derived from Proposition 1. The error terms are given by the random shocks, ε_d and ε_c, and θ, which can be interpreted as a term of unobserved heterogeneity. We follow Perrigne's (2002) identification strategy and estimation procedure. The basic idea is to parameterize the model structure $[q(\cdot), C(\cdot), F(\cdot)]$, while minimizing the assumptions on ε_d and ε_c and exploiting the independence of ε_d and θ. We consider a demand function with constant price elasticity, $q(p, \varepsilon_d) = \exp(d_0)\mathbf{Z}_d^{d_1}p^{d_2}\exp(\varepsilon_d)$, where $\mathbf{Z}_d$ is a vector of exogenous variables. We consider a Cobb-Douglas technology, in which the adverse selection variable affects labor efficiency. This gives the variable cost function $C(\theta, q, K, \varepsilon_c) = \exp(\beta_0)\exp(\beta_L\theta)p_L^{\beta_L}p_E^{\beta_E}q(p)^{\beta_y}K^{-\beta_K}\mathbf{Z}_c^{\beta_c}\exp(\varepsilon_c)$, where p_E and p_L denote the price for energy and labor, respectively, and $\mathbf{Z}_c$ is a vector of exogenous variables. Homogeneity of degree 1 can be imposed. Regarding the firms' type density, we choose a Gamma density for its flexibility, i.e., $f(\theta; r, \gamma) = \gamma(\gamma\theta)^{r-1}\exp(-\gamma\theta)/\Gamma(r)$, where r is a positive integer and $\Gamma(r) = \int_0^\infty x^{r-1}\exp(-x)\, dx$.

Given the multiplicative random shocks, it is natural to assume $E[\exp(\varepsilon_d)|\mathbf{Z}] = 1$ and

[1] The lower index refers to the partial derivative of the function.

$E[\exp(\varepsilon_c)|\mathbf{Z}] = 1$, where $\mathbf{Z}$ is a vector of exogenous variables. We do not make any distributional assumption on ε_d and ε_c. Identification of the model relies on the independence of θ and ε_d conditionally on $\mathbf{Z}$, i.e., $\theta \perp \varepsilon_d|\mathbf{Z}$. In addition to the demand and cost, the price and capital equations in Proposition 1 define the econometric model.[2] Because $p(\theta)$ and $K(\theta)$ can create a problem of endogeneity, we need to solve the system in p and K given θ. Given the potential measurement error on capital, we prefer to use the price equation. Thus, the econometric model is made of the demand, cost, and price equations, while the error terms are ε_d, ε_c, and θ. It gives

$$\text{(D)} \qquad q_i = \exp(d_0)\mathbf{Z}_{di}^{d_1} p_i^{d_2} \exp(\varepsilon_{di})$$

$$\text{(C)} \qquad C_i = \exp(\beta_0) p_{Li}^{\beta_L} p_{Ei}^{\beta_E} q_i^{\beta_y} K_i^{-\beta_K} \mathbf{Z}_{ci}^{\beta_c} \exp(\beta_L \theta_i) \times \exp(\varepsilon_{ci}),$$

$$\text{(P)} \quad \log p_i = \frac{1}{(d_2+1)(\beta_K+1) - d_2\beta_y} \times \{\eta + \beta_L \log p_{Li} + \beta_E \log p_{Ei} + \beta_c \log \mathbf{Z}_{ci} + (d_1\beta_y - d_1\beta_K - d_1) \log \mathbf{Z}_{di} + \beta_K \log \delta_i + \xi(\theta_i; r, \gamma)\},$$

$i = 1, \ldots, 192$, where $\eta = -\beta_K \log \beta_K + (\beta_K + 1)\log \beta_y + \beta_0 + d_0(\beta_y - \beta_K - 1) + \log E_P$, $E_P = E[\exp(\beta_y\varepsilon_d + \varepsilon_c)]$, and $\xi(\theta) = \beta_L\theta + \log[1 + \beta_L(F(\theta; r, \gamma)/f(\theta; r, \gamma))]$. Note that p_i in (D) is not endogenous because $p(\theta_i)$ and $\theta_i \perp \varepsilon_{di}|\mathbf{Z}$.

The parameters to be estimated are d_0, d_1, d_2, β_0, β_L, β_E, β_K, β_c, r, γ; while the observables are q_i, $\mathbf{Z}_{di}$, C_i, p_{Li}, p_{Ei}, δ_i, $\mathbf{Z}_{ci}$, $i = 1, \ldots, 192$. The estimation method is multistep. Using $E(\exp(\varepsilon_{di})|\mathbf{Z}_i) = 1$, the first step estimates d_0, d_1, and d_2 using a nonlinear GMM estimator. Using the orthogonality condition $\theta_i \perp \varepsilon_{di}|\mathbf{Z}_i$, the second step estimates β_L, β_E, β_c, and β_K using a linear GMM estimator. The third step estimates $\beta_0 + \log E_P$ and (r, γ). Note that (P) provides $\log p_i = \psi(\theta_i; \beta_0 + \log E_P, r, \gamma)$, since the other terms in (P) are either observed or estimated. For $r = 1, 2, \ldots$, a method of simulated moments is used to estimate $(\beta_0 + \log E_P, \gamma)$. The computation of additional moments allows us to assess the best adjustment for r. Using these estimates, we can recover θ_i, $i = 1, \ldots, 192$ from (P).[3]

TABLE 2—ESTIMATION RESULTS

Variable	Coefficient	t-ratio
Constant	−1.5738	−1.66
Water price	−0.2946	−4.96
Population	1.0285	37.77
Income	0.5155	5.60
North	−0.2014	−3.49
Population/pipe	−0.2039	−3.18
Labor price	0.1975	2.63
Energy price	0.4776	3.38
Water	1.2590	4.78
Rainfall	−0.0028	−0.01
γ ($r = 1$)	1.0434	0.35

III. Estimation Results and Policy Experiments

Estimation results are displayed in Table 2. The demand parameters have the expected magnitude. The demand is quite inelastic with a price elasticity at −0.29 as found in previous studies. There is a significant revenue effect with a revenue elasticity at 0.52. Households living in Northern California tend to consume less water than those in Southern California. The ratio population by pipe footage is used as a proxy for population density. Thus, larger population density areas tend to consume less water with an elasticity equal to −0.20. The production process tends to exhibit decreasing returns to scale though they could be considered as constant. Since homogeneity is imposed, the parameter for capital is equal to 0.3249. Rainfall has a negative impact on costs as districts with more rainfall are expected to have water sources in proximity, thereby reducing costs. The case $r = 1$ provides the best fit with γ equal to 1.04 giving $E(\theta) = 0.9617$, suggesting a concentration of efficient firms. These results can be used to assess whether the regulator has implemented

[2] Note that (p, q, C, K, T, R) are endogenously determined by the model, while the econometric model contains only three error terms leading to a singular model. We consider only the three equations determining (q, p, C).

[3] This multi-step estimation procedure does not provide valid standard errors, except for the first step. Bootstrap methods can be used to compute standard errors.

the optimal regulation through T and $\bar{R}$. After elementary algebra, $R^*(\theta) = \delta + [(\int_{\theta}^{\bar{\theta}} E[C_\theta(s, K^*(s), q(\underline{p}^*(s), \varepsilon_d), \varepsilon_c)]\, ds + U(\bar{\theta}))/K^*(\theta)]$, where $U(\bar{\theta})$ is the profit value for the least efficient firm and $T^*(\theta)$ is given in Proposition 1. The optimal monthly access fee and the optimal rate of return should be equal on average to \$19 and 0.14, respectively. Both values are somewhat larger than the observed ones (see Table 1) with a larger range of values leading to more discrimination among firms. These results suggest that (a) the model provides a reasonable fit to the data, and (b) the CPUC tends to be cautious in the rents given to firms.

Under complete information, the price would be about 10.7 percent less on average than the observed one, resulting in an increase of 3 percent in water consumption. The monthly access fee would be about \$4. These two factors lead to an increase in consumer surplus of 6.7 percent, while considering a maximum consumer willingness to pay for water of \$10. The capital stock would be about 16.9 percent lower, while the firms' profit would be equal to zero by definition. We note the parallel with the Averch-Johnson effect. Overcapitalization follows asymmetric information and allows firms to self-select in the desired way. As such, the cost of asymmetric information is quite substantial. The simulation of a price cap under asymmetric information leads to a uniform water price of about \$2.80. All the firms would be subject to the cap as their monopoly prices would take larger values than $\bar{p}$. This larger price would result in a reduction of expected consumption of 30 percent and a reduction in consumer surplus of 23 percent. The capital stock chosen by firms would be about 35 percent less, as it would not be subject to any distortion. This would result in a substantial increase in firms' profit. When considering the social welfare defined as the sum of the consumer surplus and the firms' profit, this increase in firms' profit does not, however, counterbalance the loss in consumer surplus. As such, our results suggest that the actual regulation provides a superior outcome.

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