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Casarin, Ariel
Mercadier, Augusto

How Tight the Cap?
Evidence from a Natural Experiment

Ariel A. Casarin[†]
Augusto C. Mercadier[*]

Very Preliminary Draft

Abstract

La distribución de gas natural de Argentina está sujeta a regulación price cap. Este esquema provee fuertes incentivos para mejorar la eficiencia productiva. Estimamos de manera empírica la causalidad de los valores de price cap sobre los costos de eficiencia por medio de cambios exógenos en sus niveles para el período 1993-2008. Para hacerlo, construimos una frontera de costos eficiente y determinamos el efecto del valor del price cap sobre la distancia a la frontera de costos. Encontramos que cuanto más exigente es el price cap, mayor es la convergencia de las empresas a nieles comparables de eficiencia en costos.

Argentine natural gas distribution industry is subject to price cap regulation. This kind of regulation provides high-powered incentives for productive efficiency. We empirically examine the causal effect of price caps on cost efficiency by means of exogenous re-settings in the levels of price cap for the period 1993-2008. To do that, we construct an efficient cost function frontier and determine the effect of this variable on the distance to this frontier function as well as other regulatory changes. We find that that the tighter the cap the more firms' converge to comparable levels of cost efficiency.

Key Words: Incentive regulation; quality; stochastic frontier; gas utilities

JEL: L11, L51, L95

[†] Escuela de Negocios, Universidad Adolfo Ibañez, Chile. Ariel.Casarin@uai.cl
[*] ERAS & Universidad Nacional de La Plata, Argentina. amercadier@econo.unlp.edu.ar

1. Introduction

Asymmetric information between regulators and firms is a key issue in regulatory practice. Incentive regulation models seek then to provide regulated firms with the incentive to use their exclusive information on effort and costs to improve operating efficiency and investment decisions and hence to ensure that consumers benefit from efficiency gains.[1] Largely since Shleifer (1985), the theory of regulation under information asymmetry has instituted the regulatory benchmarking of firms' costs by means of comparing a firm's actual performance against some predefined reference, or benchmark.[2] A perceived advantage of regulatory benchmarking – which is usually implicit in price caps – is that it reduces the problem of asymmetric information by reducing the regulator's reliance on firms' own costs – which is typical of rate of return regulation – but references the price to external, influence-free, benchmarks (Bernstein and Sappington, 1999).

Firms, on their part, can exploit strategically incentive regulation mechanisms.[3] Regulated firms might be tempted to collude so as to reduce cost reducing effort if they realize that they are played out against each other (Laffont and Martimort, 2000; Tangerås, 2002; Potters et al, 2004).[4] Likewise, firms can game regulators through the timing of specific type of actions inherent in the cyclicality of regulatory reviews – the so-called ratchet effect (Freixas et al., 1985, Dalem, 1995). Strategic behavior in cost reducing effort may thus lead to foregone efficiency improvements (Jamasb et al., 2004). In response, some regulators add a stretch factor to the basic price cap formula. The stretch factor reflects an estimate of the extent to which cost efficiency is expected to increase above historic levels because of the enhanced incentives for efficient operation that incentive regulation, in fact, aims to create (Sappington and Weisman, 2016). Yet, stretch factors and cost reduction effort are not endogeneity free, so it is difficult to unequivocally predict how firms react to a further tightening of price caps.

[1] Baron and Myerson (1982) and Laffont and Tirole (1986) address regulation of monopoly firms in the presence of asymmetric information in the form of unknown costs and unobservable effort to reduce costs.
[2] The notion of yardstick competition coined by Shleifer (1985) seeks to deduce from all firms under the regulatory mechanism the regime for a particular firm, where the price the regulated firm receives depends on the costs of identical firms.
[3] Our focus is on strategic behavior related to operating performance. We therefore leave aside strategic behavior aimed at regulatory capture (see Dal Bo, 2006)
[4] The collusive contract in Tangerås (2002) is *ex-ante*, whereas in Laffont and Martimort (2000) it is *ex-post*. In Potters et al. (2004) participants collude within a repeated game setting.

We seek an empirical answer to such a question. Our central concern is to examine whether a further and exogenous tightening of a price cap causally affects firms' productive efficiency and to detect the direction of such changes, if any. Theoretical predictions are not unequivocal. A more stringent price cap should lead to stronger incentives for managerial effort, regardless of firm type (high or low cost). Yet, if price caps are set too low, indirect effects might counterbalance the beforehand direct effect. First, a too stringent price cap decreases the utility of cost reduction effort – if negative, managers may exert less effort than before the resetting of the new cap.[5] Second, if the value of cost reduction decreases, the owner of the firm may be less inclined to pay the manager in order to induce higher effort, and she may even prefer to liquidate it (Schmidt, 1997). All in all, the effect of lower price caps on cost reducing effort is thus ambiguous. The response is mainly empirical.

We empirically examine the causal effect of price caps on cost efficiency by means of exogenous re-settings in the levels of price cap, which take the form of unexpected increases in either X or stretch factors. Our empirical setting is the Argentine natural gas distribution industry from its privatization in late 1992 to 2008, and our identification strategy exploits a natural experiment based on Argentina's default on its sovereign debt. The experiment rests on the enactment of the Public Emergency and Exchange Regime Reform Act of 2002, which led to a significant drop of real tariffs across all the utilities sectors in Argentina. This reform provides us with an exogenous change in the level of tariffs of price cap regulated firms. Our study period includes relevant variation in both the regulatory enforcement of a price cap mechanism and therefore it permits a methodical assessment of the potential link between the incentives of high-powered incentive schemes and productive efficiency.

Our strategy is to estimate a number of alternative specifications of a stochastic frontier variable cost function. We take the position that firms' costs off the frontier reveal managerial choices in the allocation of inputs, or effort. We use a 'true random-effects' model, which is a random-constant frontier model obtained by combining a conventional

[5] This effect depends on the manager's wealth constraint and his disutility in case of liquidation.

random-effects model with a skewed stochastic term representing inefficiency. These models include separate stochastic terms for latent heterogeneity and inefficiency, and therefore assume that firm-specific heterogeneity does not change over time but sources of inefficiency vary both across firms and over time. A particular feature of our study is that we examine how quality affects regulated firms' production technology (Kwoka, 2005; Saal et al., 2007; Destandau and Garcia, 2014) The evidence, which ignores strategic behavior, suggests that quality features have an impact on firms' costs and in comparative productive efficiency assessments. Put differently, it confirms that quality provision is not cost free. In our paper, quality is recognized as endogenous and observed by means of measured indicators.

Our paper therefore adds in several ways. First, we contribute to the literature that examines how incentive regulation mechanisms affect the pattern of firms' productive efficiency throughout regulatory cycles (Di Tella and Dyck, 2002; Botasso and Conti, 2009; Casarin, 2014). Second, our work is to some extent related to the industrial organization literature that examines how competition – in our case conceptually mimicked by the stringency of the price cap – affects some form of productive efficiency; see Van Reenen (2011) for a review. Finally, we also add to the very few studies that examine productive efficiency in the distribution of piped gas (Farsi et al., 2007; Casarin, 2014; Tovar et al. 2015). To best of our knowledge, ours is the first study to include realized service quality features to model the productive technology of gas distribution utilities.

We find that the tightening of the price-cap brings variation in firms cost efficiency. We also find that the formal introduction of quality regulation made firms to become more cost efficient. The rest of the paper is organized as follows. Section 2 provides background on Argentina's natural gas distribution market and on the regulatory developments that give place to our identification strategy. Section 3 presents the methodological framework. Section 4 describes the data and the measures used in the empirical estimates. Section 5 presents the main results. The last section concludes.

2. Empirical Setting

The Argentinean natural gas distribution industry consists of eight firms, all created at once following industry privatization in December 1992. Privatization involved the enactment of a new Natural Gas Law, the creation of a national gas regulator (ENARGAS) and the deregulation of gas extraction and production. After privatization, the gas market was divided into three main players: independent gas producers, two high-pressure pipeline firms and local distributors. Gas producers are responsible for exploring for and producing natural gas in a market open to competition. Pipeline firms run transportation services, operate under an open access regime and are forbidden to trade gas. Distributors were granted 35-year licenses under a public utility obligation to supply in their franchise area. They buy gas from producers at the wellhead, pay for transportation and distribute gas to retail and large users subject to an additional mark-up.

Following privatization, regulation of the downstream gas industry became national and centralized at ENARGAS. A primary function of ENARGAS is to regulate the tariffs of transmission and distribution firms. The Natural Gas Law sets out the rules for establishing the structure and level of gas tariffs. Between 1993 and 2008, all gas users were charged using a two-part structure consisting of a fixed fee and a single unit price.[6] The (pre-tax) unit price is specified as $p = g + t + d$, where g is the gas wellhead price and t and d the transport and distribution margins, respectively. The regulation of tariffs has the properties that are characteristic of price cap regimes. The regulator was to approve twice yearly the pass-through of gas costs and the adjustment for inflation of the transport and distribution margins. These margins were also to be reviewed every five years using an efficiency factor x and a project specific investment factor k, which were both set at zero at privatization. A salient condition of the distribution licenses was the requirement that each franchise invest a minimum amount; this obligation, aimed at restoring service quality and

[6] In late 2008 ENARGAS introduced a revised schedule composed of eight new tariff groups, each facing different variable fees per cubic meter (see Bastos et al., 2015).

expanding the grid, had to be accomplished within the first price review period (Casarin, 2014).[7]

Perhaps the most significant feature of the price cap regime was that tariffs were set in US dollars and then converted into local pesos at the official exchange rate established by the Convertibility Law.[8] Since this Law explicitly forbade the indexation of contracts written in pesos, tariffs were to be adjusted semi-annually according to changes in the Producer Price Index of the US. As a result, distribution margins for each user category were adjusted twice-yearly making $d_t = d_{t-1} [i_t / i_{t-1} – (x + k / 100)]$, where d_t is the tariff level at time t, i the Producer Price Index of Industrial Commodities in the US, x an efficiency factor and k a project specific investment factor. The x and k factors were to be reset at price reviews, which were scheduled to occur every five years.

The first price revision was initiated in early 1996 and implemented in late 1997 (Gomez-Lobo and Foster, 1999). One of the main issues dealt with during the review concerned the resetting of the x factor, or productivity offset. The regulator considered the overall productivity gains for the whole industry and proposed x factors computed as the average cost reduction that each firm could achieve if it introduced specific efficiency plans. The factors set by the regulator ranged from 4.8 to 4.4 and were all applied in a one-off fashion in January 1998, at the start of the second review period. Several firms expressed their disagreement with the method used for computing potential efficiency gains as well as with the full application of x at the start of the review period. Ultimately, the disagreement was not disputed in the judiciary.

The regulator has been concerned with quality issues since the privatization. The office has consistently collected and published several quality measures such as the number of leaks per kilometre of distribution network, the number of leaks in metering equipment per user and billing claims per customer, for example. However, in January 2000 ENARGAS made

[7] Another salient feature of the system was the firms' lack of flexibility for setting individual prices subject to an aggregate revenue or tariff basket constraint. The regulator therefore establishes maximum rates for all services and user categories.

[8] The Convertibility Law, established in 1991, introduced a fixed exchange rate regime that pegged the peso at par with the dollar. This regime was abandoned in early 2002 when a significant devaluation of the local currency occurred.

effective an explicit quality control system. For gas distributors, the system consists of separate technical and commercial quality indicators. The commercial quality indicators evaluate the performance in all those activities in which distributors interact with their customers, while the technical quality indicators consider the transparency of the market, the protection of the environment and the secure operation and maintenance of the distribution grid. Since 2002, franchisees are compelled to satisfy the reference standards for a specific performance index. Performance is evaluated annually, no swapping between standards is allowed and the regulator fines failure. The system is a "one direction model" because recompenses are not considered.

The major event affecting the sector has undoubtedly been the macroeconomic crisis of 2002 –and the subsequent government reaction to it. In January 2002, a new government passed an Economic Emergency Law that put an end to the fixed exchange rate regime set forth in the Convertibility Law. In February 2002 the peso was allowed to float freely.[9] The Economic Emergency Law mandated the conversion of all utilities' tariffs from dollars to pesos at the pre-devaluation fixed exchange rate. It also required firms to observe all their contractual and regulatory obligations notwithstanding the modification of their contracts.[10] As part of this process, the government directed ENARGAS to cease all ongoing tariff reviews, including the second five-year tariff review scheduled for 2002, and to refrain from any tariff or seasonal price adjustment. In 2003, the government established the Unit of Analysis and Renegotiation of Public Service Contracts (UNIREN) to renegotiate 64 utility contracts (including water, transport, telecoms and gas, as well as electricity).[11] Negotiations were difficult and subject to political gaming as the government made price controls an important part of its electoral strategy.

Initially, the Economic Emergency Law was to be valid until December 2003. Since then, however, the 2002 law was successively extended, each time for one year and through the passing of a new short law that only extended the legitimacy term of the original law. In late 2008, UNIREN sent gas distribution firms an interim agreement providing for the

[9] The Peso collapsed to less than 30% of its 2001 value, and Argentina defaulted on its foreign debt.
[10] The Economic Emergency Law suspended the contractual terms of more than 60 firms in the energy, sanitation and transportation sectors. Haselip (2005) and Pollitt (2008) offer a detailed account of its impact on the electricity industry.
[11] UNIREN replaced an earlier agency created in 2002.

granting of a transitional adjustment in tariffs and conducting to an Integral Tariff Review, by which a new system of maximum rates shall be fixed for the term of five years, as stipulated in the regulatory framework. In late 2008, ENARGAS introduced the first increase in residential tariffs since 2002.

3. Econometric specification

All firms in our sample have the obligation to provide the service of gas distribution to a given number of customers on a given geographical area. Output is therefore exogenous and firms' objective is to minimize costs. The provision of the gas distribution service requires the use of capital, labor and other intermediate inputs, and also of managerial effort in the form of coordination and supervision of the input factors. However, capital inputs are tightly dependent upon the extent of service and therefore exogenously fixed in the short run. Scale economies in infrastructure construction also make capital a quasi-fixed input that adjusts partially to long run equilibrium levels (Casarin, 2014). We allow explicitly for such disequilibrium and consider that firms minimize operating costs. Variations in cost efficiency, which we relate to managerial responses to regulatory practice, are then largely connected with non-minimizing behavior of operating expenses.[12]

We also consider that quality is observable after consumption but unverifiable (see Sappington, 2005). We take the position that quality is an experience good that does not provide a sales incentive but a reputation incentive. The provision of quality is then linked with the firm's desire to keep its reputation and preserve future profits (in the form of the trade incentives represented in Laffont and Tirole, 1993).[13] Hence, we write quality independent from the production technology. The cost function for firm i then becomes:

$$C = \beta + s - e \quad (1)$$

[12] Our approach mimics Leibenstein's (1978) X-efficiency proposition: the lower the intensity of an environmental pressure on a decision-maker, the less is her concern with the constraints operating on the organization and, consequently, the lower is the effort expended. This reduced effort leads to higher costs, regardless of the techniques involved.

[13] The fact that gas regulators rely on indicators such as consumer complaints reveal that that quality is unverifiable.

where β is a parameter that captures the production technology, s the level of quality and e the effort to reduce cost.[14] The specification assumes that quality and effort are separable from the technology parameter β. Note that in (1) a scale effect is only in β, that moral hazard is two-dimensional (in s and e) and that quality enters (1) in hedonic form.[15]

Productivity in (1) consists of an industry-specific part, known to all firms in the industry, and a firm-specific part, known only to each particular firm. Expenditures on quality improvement and managerial effort are both unobservable, but cost is observable and a quality indicator provides a signal of quality. Under this set-up, expenditures on quality improvement are unverifiable because quality is only an imperfect signal of expenditures, and the expenditures themselves cannot be observed directly. Equation (1) also makes evident that the provision of quality and cost reducing activities are substitutes. Given the technology, to reach the same cost, an increase in quality must be compensated for with an increase in effort.

Our main goal is to provide a better understanding of the effects of regulatory practice on cost efficiency (considering service quality), rather than to provide the best global approximation of the production technology of gas firms. When – as in our case – the objective is to identify and explain rather than to predict, a simple approximation of the cost function performs well at the mean point. We consider a Cobb-Douglas function, which implicitly assumes separability between outputs and inputs. The restricted cost function we estimate does not entail all second-order terms to account for the most flexible representation of the technology.[16] We however choose this specification to retain enough degrees of freedom to incorporate as much heterogeneity into the cost function as we can observe. We do this by considering several variables to examine how spatial and environmental factors shape the production technology and have an exogenous effect on

[14] We hold the usual assumption that effort e involves disutility $\psi(e)$ with $\psi' > 0$, $\psi'' > 0$ and $\psi''' \geq 0$.

[15] When quality is verifiable, its level on a given product can be treated as the quantity of another fictions product, in which case quality features are treated as exogenous outputs of a multiproduct production technology (ie., quality enters β as in Saal et al. 2007 and Growitsch et al. 2009). Our specification treats quality as an hedonic variable, as first derived by Spady and Friedlaender (1978), who define quality as "an attribute associated with the physical output." Destandau and Garcia (2014) review alternative approaches.

[16] The effects of second-order terms are suppressed into the error components, so they could potentially have a similar effect as that of omitted variables. Yet, since the Cobb-Douglas is nested in the more flexible translog functional form, we estimate a non-stochastic translog variable cost function and test for parameter restrictions. See Annex 1.

costs.[17] We believe that we reach a good compromise to produce meaningful and hopefully robust results.

Unobserved heterogeneity presents a greater challenge. It generally enters the stochastic frontier through either fixed or random effects. This approach can however confound cross-firm heterogeneity with the inefficiency term, leading to biased estimates. We address this concern making use of Greene's (2005) true random-effects model, which separates time-variant inefficiency from time-invariant unobserved heterogeneity.[18] We therefore estimate a variable cost function of the form:

$$(2) \qquad vc_{it} = (\alpha + \alpha_i) + f(\mathbf{x}_{it};\boldsymbol{\beta}) + \mathbf{s}_{it} + v_{it} + u_{it}$$

where vc_{it} is (the log of) variable cost for firm i at time t, α is a common intercept, α_i a random effect that represents time-invariant firm specific unobserved heterogeneity, and $f(\mathbf{x}_{it};\boldsymbol{\beta})$ is the production technology: $\mathbf{x}_{it}$ is a vector of variables representing outputs, input prices, capital inputs and industry technical change, while $\boldsymbol{\beta}$ is a vector of parameters.[19] The term $\mathbf{s}_{it}$ is a vector of quality variables, while v_{it} and u_{it} are the two parts of a composed random error, $\varepsilon_{it} = v_{it} + u_{it}$, where v_{it} represents a random error term that captures noise as well as any firm and time-specific unobserved heterogeneity, while u_{it} signifies time-varying firm-specific inefficiency. We adopt the following distributional assumptions:

$$(3) \qquad \alpha_i \sim \text{iidN}\,(0, \sigma_\alpha^2)$$

$$(4) \qquad v_{it} \sim \text{iidN}\,(0, \sigma_v^2).$$

$$(5) \qquad u_{it} \sim \text{iidN}^{+}(0, \sigma_u^2) = \text{iidN}^{+}(0, \exp\,(\omega_{u0} + \mathbf{z}_{u,it}\omega_u))$$

The variance function of u_{it} consists of a constant term ω_{u0}, a vector of variables $\mathbf{z}_{u,it}$ that explain inefficiency differences –and therefore key to provide evidence to our research

[17] For example, the amount of gas distributed and the extension of pipeline networks are closely related to the number and type of customers served and the area over which they are scattered.
[18] Kumbhakar (1991) proposed a similar approach using a three-stage estimation procedure.
[19] We reckon that models that allow time-invariant effects but do not treat them as inefficiency provide lower inefficiency estimates– see Khumbakar et al., (2014). Therefore, we also test our data using other stochastic frontier models that differ in their assumptions about the distribution of the error components and in their estimation approach. See Annex 2.

question, and the corresponding vector of coefficients ω_u.[20] The firm's inefficiency is estimated by the conditional mean of the inefficiency term $\hat{u}_{it} = E[u_i \mid \hat{w}_{it}]$, where $w_{it} = \alpha_i + \varepsilon_{it}$.[21] The true random-effects model assumes that the terms α_i, v_{it} and u_{it} are uncorrelated with the explanatory variables and each other. The estimates are obtained by the maximum simulated likelihood method.

The model we estimate assumes that unobserved cost differences across firms remain constant over time and that they are driven by firm related unobserved characteristics, rather than inefficiency. We believe this is a realistic assumption given the relatively long period covered in our data (16 years). The distributional assumption we adopt for the inefficiency term implies that inefficiency is not persistent and that each period brings about new idiosyncratic elements and, accordingly, new sources of inefficiency. This is a reasonable assumption when firms face frequent regulatory changes. We conjecture that the sources of inefficiency are dominated by unanticipated regulatory shocks (and the reaction of managers facing them). We therefore include in $\mathbf{z}_u$ several variables to examine how the unanticipated i) introduction of quality standards, ii) tightening of the price cap and iii) further liberalization in the contract market affect firms' efficiency; we also include in $\mathbf{z}_u$ other variables to control for principal-agent features that may also affect managerial effort.

Stochastic frontier analysis assumes that u and v are uncorrelated with cost equation variables and each other. However, our empirical approach is prone to at least three sources of endogeneity.[22] First, quality and v can be positively related (the endogeneity is in v) if some firms make capital additions that bring along quality improvements but also command lower operating costs.[23] Since our measure of capital stocks reduces all sorts of capital into a single variable, any capital embodied quality change would be swept into the error and there would be a positive relationship between quality and v. Given the nature of

[20] This approach follows Caudill and Ford (1993), Caudill et al. (1995) and Hadri (1999)

[21] The fact that all time-invariant effects are treated as unobserved heterogeneity and are captured by the firm-specific constant implies that any persistent inefficiency is not included in the inefficiency term. As a result, the true random effects model tends to underestimate inefficiency (Farsi et al, 2006).

[22] We have no concern with the variables that enter X. Output quantities are demand driven, and variable input prices result from competitive markets. Capital stocks were largely inherited at privatization, which also mandated compulsory investments during the first review period.

[23] For example, think of an ERP system that brings improvements in reading and billing, which becomes electronic, and that consequently reduces operating expenditures.

capital in this industry, we however presume that the strength of the endogeneity is small. Secondly, another source of endogeneity results when the allowed price level is made dependent on quality improvements (the endogeneity is in u).[24] In our case, however, the exogeneity of price changes that dominates our empirical setting reduces any potential endogeneity between the power of price incentives and service quality. Since in both cases the strength of the endogeneity is small, we follow of Mutter et al. (2013) and retain quality in our estimates.

Finally, another source is the potential endogeneity of the regulatory regime itself, as incentive regulation might have been adopted with the confidence that service quality will improve over time, regardless of the regulatory regime.[25] An observed correlation between incentive regulation and improved quality would not provide then rigorous evidence that adoption of incentive regulation enhances service quality.[26] We can't rule out this source of endogeneity in our data because we observe firms' behavior soon after privatization, which was partly due to poor service quality. Quality improvements soon after privatization can then be confounded with ownership effects, regardless of the regulatory regime. This will violate the assumption that u is distributed independently of v and would result in biased parameter estimates. Still, the fact that we observe firms created all at once for privatization, and over a long period, makes us believe that any eventual bias remains smaller.[27]

We use log values for the variable costs and the independent variables in X. Prior to taking logs, the x-variables were all scaled by their sample mean. The coefficients in the cost function can then be interpreted as elasticities evaluated at the sample means. Also, the cost function must be concave and linearly homogeneous in input prices and non-decreasing in output and inputs. The Cobb–Douglas form automatically satisfies concavity, and the linear homogeneity restriction can be imposed by normalizing the monetary variables by the price

[24] This practice is followed by some regulators that let the factor X in the RPI-X price depend on quality improvements. See for example Ofwat (2002) and Saal and Parker (2001).
[25] Put differently, regulators that perceive service quality is poor may be particularly unlikely to adopt incentive regulation so as to avoid further quality degradation.
[26] Similarly, incentive regulation and quality standards may be endogenous because they are more likely to be imposed when the utility has a poor performance.
[27] Mutter et al. (2013) suggest that researchers will get more accurate inefficiency estimates by including the endogenous variable than excluding it if the endogeneity is due to a relationship with v.

of one of the input factors. We verify the other theoretical restrictions after the estimation.

4. Data and Variables

The data set consists of all piped gas distribution firms operating in Argentina from 1993 to 2008. The firms that we examine were all created at privatization, so there are no differences in privatization method and timing that could potentially affect performance across firms. The data come from public sources. Cost data come from firms' annual reports. We obtained disaggregated data on gas deliveries, number of users, quality indicators and records of consumer complaints from ENARGAS' quarterly and annual statistical bulletins; this office also provided the series of full-time employees. Price indexes and data used in computing spatial and environmental variables all come from the National Statistics Institute (INDEC).

Our dependent variable, total variable costs, results from the sum of operation and maintenance expenses. We exclude depreciation, costs attributable to capital projects and provisions for bad accounts or other contingencies. We also exclude the costs of gas and of transmission services, which are fully passed through to final users. We can separate variable costs into labor (sum of total salaries, wages and employee benefits) and intermediate inputs (materials, office services, maintenance and so forth). We model the production technology β in a multi-output form, where gas deliveries capture output of the distribution stage and the number of costumers seizes output of the supply stage.[28] We also consider two variable inputs. The unit price of labor is the ratio of labor costs to the average number of full-time employees. We also estimate the price of other intermediate inputs by dividing the total of non-labor expenses (computed as total variable costs minus labor costs) by the ratio of users to network length. We then deflate costs and input prices to mid-sample real values using the wholesale price index.[29]

[28] See for example Fabbri et al., (2000); Carrington et al., (2002) and Casarin (2014). See also Burns and Weynman-Jones (1998) for estimates of the production technology of gas retailing. In our sample, domestic customers account for 95% of the total customer base.
[29] We use the Indice de Precios Internos al por Mayor (IPIM).

We represent the magnitude of capital stocks with the length of the pipeline network. We prefer this measure to the one that gives the perpetual inventory method because of potential distortions in the purchase price of assets following 2002, and also because network length is a fairly good instrument to reduce the endogeneity between capital and quality commented above.[30] We use two variables to capture alternative features of service quality at the firm level. We account for technical quality using both pipeline leaks (per kilometer of pipeline network) and meter leaks (per user), which we add up into a single variable. We measure commercial quality with the number of complaints.

We use several variables to account for the exogenous effect of environmental and spatial factors on operating costs. We compute a load factor variable, which for each year is the ratio of monthly maximum to annual average demand. Also, distributors generally incur greater costs in delivering gas to tariff customers (residential and small commercial) than to contract (industrial and power plant) users because more infrastructure and services are needed to supply gas to tariff users. We thus compute a variable that relates for each year the proportion of tariff market to total gas deliveries. We also account for spatial differences using a measure of population density for each franchise area. Finally, we also control for a potential shift in the structure of costs in 2002 with a dummy viable that equals 1 in 2002, and zero otherwise.

Our dominant goal is to examine the effect of regulatory interventions on firm efficiency. The key variable is the one that captures the tightening of the price cap. We compute two versions of this variable. Prior to 2002, both versions result from one minus the cumulative value of the *x*-factors set at privatization (1993-1997) and also the ones that ensued the first price review (1998-2001). Following 2002, when firms' tariffs remained nominally fixed, we compute *de facto x*-factors making $P_t - P_{t-1}$, where P is the level of counterfactual real tariffs had the regulatory contract remained effective (the initial P_{t-1} is 2001). We refer to this version of the variable as Effective X Regulatory Practice. The other version corrects the tightening by the difference between Argentina's CPI and the US PPI rate, which is the

[30] The correlation between the capital stock measure using perpetual inventory method and network length over the entire sample period is 0.505. Between 1993 and 2001, the correlation between the two variables is 0.761, but it reduces to 0.321 between 2002 and 2008.

inflation reference established in the regulatory framework. We refer to this version of the variable as Effective X Regulatory Design.

We also account for the formal introduction of quality standards with a dummy variable that equals 1 between 1999 and 2008, and 0 otherwise. Also, a dummy that equals 1 between 2005 to 2008 and 0 otherwise, captures the reduction in the consumption threshold that permits competition in the contract market. Finally, we use the firms' leverage (computed as debt to equity) to control for other principal-agent features that may also affect managerial effort. Table 1 provides data summary statistics.

[Insert Table 1 about here]

5. Results

We estimate alternative specifications of equation (2). We examine alternative specifications. Models A and B are the baseline models and they only differ in the definition of the X-factor. Provided leverage had no effect on the inefficiency term, Models C and D replicate models A and B without this variable. In models A to D quality variables have no effect on the cost structure. In models E and F we add the square of the two quality variables to explore for possible non-linear relationship between quality and costs. Table 2 displays the results.

[Insert Table 2 about here]

a. The production technology

Results show that a large number of the parameters are statistically significant and that their signs are consistent with expectations. As expected, there is a positive relationship between gas deliveries, customers and input price coefficients, whose parameters do not differ significantly among models (the case for gas deliveries is weaker). As in previous studies, results indicate that the number of customers is the main driver of gas distribution costs (Fabbri et al., 2000; Casarin, 2014). All else equal, a 10% increase in the number of customers leads to a 5% increase in variable costs. All remaining elasticities are interpreted

likewise. Note that the dummy for the year 2002 has a nil or modest effect on firms costs. This finding suggests that the costs frontier remained basically unaltered throughout our study period, and therefore that the variations in efficiency we examine below are not due to changes in the production technology.

The coefficients on pipes are negative and significant in all models but D. This finding implies that an increase in the stock of capital reduces variable costs. The coefficient on the time trend variable – a proxy for technical change – is also negative; its value implies that technological progress reduces variable costs 0.5% a year. Results indicate that spatial and environmental variables contribute to explain variation on firms' costs. The coefficients on the tariff market variable are positive in all models but in F (p-value is 17.5%), which implies that it is more expensive to supply this type of users. The coefficient of the load factor variable is statistically significant in Models E and F only; this suggests that it is more costly to serve areas where consumption is more volatile (Bernard et al., 1998; Farsi et al., 2007). Next, the coefficient on density is positive, meaning that more densely areas are most difficult to serve.

Quality variables appear to have a non-linear effect on variable costs, as their linear forms are not statistically significant but their squared terms are. Specifically, claims depict an inverted U-shape relationship. If cost of managing a small number of complaints appears to be small, but it increases as complaints increase up to point where costs of managing them decrease, perhaps because it becomes unprofitable to manage them all. On the contrary, the effect of leaks on variable costs has a U-shape pattern, suggesting that there are economies of scale in securing this quality feature of gas distribution.

b. Regulatory developments and cost efficiency

The bottom half of Table 2 displays the coefficients that explain firms distance to the frontier.[31] Table 3 summarizes Models A to F mean efficiency scores, which are similar

[31] We tried to estimate True Fixed Effects (TFE) models allowing for free correlation between αi and the regresors, and also models applying Mundlak`s transformation on our True Random Effect model; none converged. Bottasso and Conti (2009) discharge fixed effects in favor of random effects because explanatory variables have a very low degree of within group variability.

across all models. Table 4 displays the correlation among the efficiency scores of all models, which is high. Models A and B include the leverage variable, but it proved non significant.

Results indicate that the formal introduction of quality standards in 1999 had a negative effect on the distribution of inefficiency. This finding implies that such a regulation made firms to become more cost efficient. Put differently, this regulatory feature seems to have pressured firms to produce quality conforming to the new standards at no significant increase in variable costs.

The reduction in the consumption threshold that allowed competition in the contract market has an opposite effect. This result implies that the introduction of competition is associated with an increase in the distribution of inefficiency. More efficient firms could snip users from inefficient firms, perhaps due to a cost advantage.

[Insert Table 3 and 4 about here]

Models E and F differ in the definition of the tightening of the price cap but in both cases the relation to efficiency is positive, implying that the more stringent the cap the lower the distribution of inefficiency. That is, firms seem to respond in a similar manner to this kind of regulatory pressure. That is, results indicate that the tighter the cap, the more firms' converge to comparable levels of cost efficiency. See Figure 1.

[Insert Figure 1 about here]

c. A simple robustness exercise

We reckon that variables we use to account for quality effects are not exogenous. Table 5 therefore displays the results of some simple robustness exercises we perform to address the endogeneity of our realized service quality variables. We run four models. Model G and H exclude all quality variables, while Models I and J include the lagged quality variables.

In all four cases, the coefficients of the parameters that define the production technology remain practically invariant. This means our estimates of the frontier are considerably robust and stable to alternative specifications of quality. Model I presents the best estimates. As before, results indicate that formal introduction of quality regulation made firms to become more cost efficient, and that the more stringent the cap the smaller the inefficiency.

[Insert Table 5 about here]

6. Conclusion

The problem of asymmetric information is central to the regulation of utilities. One way to address is concern is the use of regulatory benchmarking of firms costs. The aim of benchmarking within incentive regulation is to exploit the potential for cost efficiency improvement of the regulated firm. This is not an easy task. As a result, how to determine efficiency improvements, which ultimately translate into tariff changes, has turned into a highly contentious issue in price and revenue cap regulation. It is difficult to unequivocally predict how firms react to a further tightening of price caps. The response is mainly empirical.

Our paper examines how large information asymmetries might be, as it examine whether a further and exogenous tightening of a price cap causally affects firms' productive efficiency. In our paper, quality is recognized as endogenous and observed by means of measured indicators. We find that the tightening of the price-cap brings variation in firms cost efficiency. We also find that the formal introduction of quality regulation made firms to become more cost efficient.

References

Baron, D. P., & Myerson, R. B. (1982). Regulating a monopolist with unknown costs. *Econometrica: Journal of the Econometric Society*, 911-930.

Bastos, P., Castro, L., Cristia, J., & Scartascini, C. (2015). Does Energy Consumption Respond to Price Shocks? Evidence from a Regression-Discontinuity Design. *The Journal of Industrial Economics*, *63*(2), 249-278.

Bernstein, J. and Sappington, D., (1999). Setting the X Factor in Price-Cap Regulation Plans. *Journal of Regulatory Economics* 16: 5 – 25.

Bottasso, Anna, and Maurizio Conti. "Price cap regulation and the ratchet effect: a generalized index approach." *Journal of Productivity Analysis* 32.3 (2009): 191-201.

Burns, P., and Weyman-Jones, T. G. (1998). Is the gas supply market a natural monopoly? Econometric evidence from the British Gas regions. *Energy economics*, *20*(2), 223-232.

Casarin, A. A. (2014). Productivity throughout regulatory cycles in gas utilities.*Journal of Regulatory Economics*, *45*(2), 115-137.

Dal Bó, E. (2006). Regulatory capture: a review. *Oxford Review of Economic Policy*, *22*(2), 203-225.

Dalen, D. M. (1995). Efficiency-improving investment and the ratchet effect. *European Economic Review*, *39*(8), 1511-1522.

Destandau, F., & Garcia, S. (2014). Service quality, scale economies and ownership: an econometric analysis of water supply costs. *Journal of Regulatory Economics*, *46*(2), 152-182.

Di Tella, R., and Dyck, A. (2008). Cost reductions, cost padding, and stock market prices: The Chilean experience with price-cap regulation. *Economia*, *8*(2), 155-185.

Fabbri, P., Fraquelli, G., & Giandrone, R. (2000). Costs, technology and ownership of gas distribution in Italy. *Managerial and Decision Economics*,*21*(2), 71-81.

Farsi, M., Filippini, M., & Kuenzle, M. (2007). Cost efficiency in the Swiss gas distribution sector. *Energy Economics*, *29*(1), 64-78.

Freixas, X., Guesnerie, R., & Tirole, J. (1985). Planning under incomplete information and the ratchet effect. *The review of economic studies*, *52*(2), 173-191.

Giannakis, D., Jamasb, T., and Pollitt, M., 2005. Benchmarking and Incentive Regulation of Quality of Service: An Application to the UK Electricity Distribution Utilities, Energy Policy 33 (17), 2256-2271.

Gómez-Lobo, A. and Foster, V. (1999). The 1996-97 Gas Price Review in Argentina. Note Number 181, Public Policy For the Private Sector, The World Bank.

Greene, W. (2005). Fixed and random effects in stochastic frontier models.*Journal of productivity analysis*, *23*(1), 7-32.

Growitsch, Christian, Tooraj Jamasb, and Michael Pollitt. "Quality of service, efficiency and scale in network industries: an analysis of European electricity distribution." *Applied Economics* 41.20 (2009): 2555-2570.

Jamasb, T., Nillesen, P., & Pollitt, M. (2004). Strategic behaviour under regulatory benchmarking. *Energy Economics*, *26*(5), 825-843.

Kwoka, John E. "The comparative advantage of public ownership: Evidence from US electric utilities." *Canadian Journal of Economics/Revue canadienne d'économique* 38.2 (2005): 622-640.

Laffont, J. J., & Martimort, D. (1997). Collusion under asymmetric information. *Econometrica: Journal of the Econometric Society*, 875-911.

Laffont, J. J., & Tirole, J. (1986). Using cost observation to regulate firms. *The Journal of Political Economy*, 614-641.

Laffont, J. J., & Tirole, J. (1993). *A theory of incentives in procurement and regulation*. MIT press.

Leibenstein, H. (1978). On the basic proposition of X-efficiency theory. *The American Economic Review*, *68*(2), 328-332.

Mutter, R. L., Greene, W. H., Spector, W., Rosko, M. D., & Mukamel, D. B. (2013). Investigating the impact of endogeneity on inefficiency estimates in the application of stochastic frontier analysis to nursing homes. *Journal of Productivity Analysis*, *39*(2), 101-110.

Potters, J., Rockenbach, B., Sadrieh, A., & Van Damme, E. (2004). Collusion under yardstick competition: an experimental study. *International Journal of Industrial Organization*, *22*(7), 1017-1038.

Saal, David S., David Parker, and Tom Weyman-Jones. "Determining the contribution of technical change, efficiency change and scale change to productivity growth in the privatized English and Welsh water and sewerage industry: 1985–2000." *Journal of Productivity Analysis* 28.1-2 (2007): 127-139.

Sappington, D. E., & Weisman, D. L. (2016). The disparate adoption of price cap regulation in the US telecommunications and electricity sectors. *Journal of Regulatory Economics*, *49*(2), 250-264.

Schmidt, K. M. (1997). Managerial incentives and product market competition.*The Review of Economic Studies*, *64*(2), 191-213.

Tangerås, T. P. (2002). Collusion-proof yardstick competition. *Journal of Public Economics*, *83*(2), 231-254.

Tangerås, T. P. (2009). Yardstick competition and quality. *Journal of Economics & Management Strategy*, *18*(2), 589-613.

Shleifer, A. (1985). A theory of yardstick competition. *The RAND Journal of Economics*, 319-327.

Spady, R. H., & Friedlaender, A. F. (1978). Hedonic cost functions for the regulated trucking industry. *The Bell Journal of Economics*, 159-179.

Tovar, Beatriz, Francisco Javier Ramos-Real, and Edmar Luiz Fagundes de Almeida. "Efficiency and performance in gas distribution. Evidence from Brazil." *Applied Economics* ahead-of-print (2015): 1-17.

Van Reenen, J. (2011). Does competition raise productivity through improving management quality?. *International Journal of Industrial Organization*, *29*(3), 306-316.

Waddams Price, C., and Weyman-Jones, T., (1996). Malmquist Indices of Productivity Change in the UK Gas Industry Before and After Privatization. *Applied Economics* 28: 29 – 39.

Table 1. Summary Statistics

Variable	Parameter	Unit	Mean	Std. Dev.	Min	Max
Variable costs		M$	116.8	80.8	28.1	392.5
Gas deliveries	β_Y	000's m3	3,133	1,624	1,071	7,948
Customers	β_c	000's	739.2	546.0	202.6	2,144.6
Pipe network	β_K	kms	12,846	5,245	4,818	24,854
Price of labor	β_{P_L}	000's $	88.62	21.69	28.70	130.73
Price of other inputs	β_{P_M}	000's $	1,259.29	700.98	389.69	3,162.50
Load	β_{Load}	times	1.287	0.191	1.053	2.834
Density	β_{Dens}	hab/km2	200.7	442.8	2.0	1,384.1
Tariff market users	β_{tariff}	%	34.7	12.8	14.8	58.6
Complaints	β_{Comp}	000's	0.564	0.589	0.106	3.778
Gas leaks	β_{Leaks}	000's	11.9	8.1	2.0	40.7
Effective X Reg. Design	ω_{XD}	%	80.0	21.7	42.0	102.5
Effective X Reg. Practice	ω_{XP}	%	78.4	23.4	39.2	100.0
Leverage (L)	ω_L	%	29.5	40.8	-	245.6

Table 2. Stochastic frontier Results

Coefficient	Model A	Model B	Model C	Model D	Model E	Model F
α	0.075***	0.064***	0.104***	0.070*	0.039**	0.200***
	(0.022)	(0.021)	(0.024)	(0.037)	(0.017)	(0.020)
β_Y	0.041**	0.010	0.027	0.022	0.086***	0.050***
	(0.018)	(0.018)	(0.019)	(0.042)	(0.016)	(0.014)
β_c	0.503***	0.477***	0.476***	0.493***	0.512***	0.491***
	(0.084)	(0.082)	(0.090)	(0.155)	(0.102)	(0.064)
β_K	-0.125*	-0.140**	-0.230***	-0.165	-0.176**	-0.166***
	(0.068)	(0.064)	(0.063)	(0.111)	(0.080)	(0.049)
β_{P_L}	0.407***	0.411***	0.417***	0.415***	0.415***	0.417***
	(0.013)	(0.012)	(0.014)	(0.017)	(0.018)	(0.010)
β_t	-0.006***	-0.004***	-0.001	-0.004	-0.005***	-0.004***
	(0.002)	(0.001)	(0.002)	(0.003)	(0.002)	(0.001)
β_{tariff}	0.267***	0.205***	0.188***	0.209***	0.128***	0.053
	(0.059)	(0.055)	(0.056)	(0.078)	(0.041)	(0.039)
β_{Load}	0.023	0.016	0.034	0.021	0.112**	0.105***
	(0.040)	(0.039)	(0.041)	(0.056)	(0.046)	(0.036)
β_{Dens}	0.045**	0.044***	0.083***	0.043	0.008	0.075***
	(0.017)	(0.017)	(0.021)	(0.035)	(0.018)	(0.015)
d_{2002}	-0.014	-0.015*	-0.018**	-0.012	-0.012	-0.015**
	(0.009)	(0.009)	(0.009)	(0.011)	(0.008)	(0.007)
β_{Comp}	0.015	0.013	0.010	0.011	-0.008	-0.008
	(0.009)	(0.009)	(0.009)	(0.023)	(0.012)	(0.008)
β_{Leaks}	0.003	0.002	0.003	0.004	0.005	0.008
	(0.008)	(0.008)	(0.008)	(0.014)	(0.006)	(0.006)
β_{Comp^2}					-0.042**	-0.043***
					(0.018)	(0.010)
β_{Leaks^2}					0.035***	0.039***
					(0.009)	(0.009)
ω_{1999}	-2.391*	-1.838**	-1.828***	-1.613	-1.590***	-1.310***
	(1.337)	(0.782)	(0.657)	(1.030)	(0.402)	(0.495)
ω_{2005}	2.748*	3.120*	1.747	2.867*	1.682***	1.581
	(1.549)	(1.814)	(1.366)	(1.616)	(0.229)	(0.996)
ω_{XD}	2.656		3.383		3.679***	
	(3.413)		(3.013)		(1.346)	
ω_{XP}		4.752		5.091		4.214*
		(3.977)		(3.242)		(2.376)
ω_L	0.826	0.718				
	(0.772)	(0.725)				
ω_{u0}	-8.920***	-10.912***	-9.148***	-10.976***	-9.358***	-9.870***
	(3.325)	(4.050)	(2.988)	(3.181)	(1.201)	(2.394)
σ_U^2	-8.733***	-8.836***	-8.874***	-8.879***	-9.797***	-10.141***
	(0.526)	(0.425)	(0.530)	(0.723)	(0.507)	(0.736)
θ	0.137***	-0.045***	0.069***	-0.040***	-0.170***	-0.067***
	(0.013)	(0.004)	(0.006)	(0.005)	(0.017)	(0.004)

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 3. Mean Efficiency Scores

Model	Mean	Std. Dev.	Min	Max
Model A	96.8%	4.0%	74.8%	99.5%
Model B	97.1%	3.8%	76.3%	99.6%
Model C	96.9%	4.1%	74.2%	99.5%
Model D	96.9%	4.2%	73.5%	99.6%
Model E	95.9%	3.8%	78.6%	99.5%
Model F	93.4%	12.8%	21.2%	99.6%

Table 4. Correlation of Efficiency Scores across Models

	Model A	Model B	Model C	Model D	Model E	Model F
Model A	1					
Model B	0.9937	1				
Model C	0.9757	0.9905	1			
Model D	0.9852	0.9969	0.9969	1		
Model E	0.8066	0.8093	0.8149	0.8118	1	
Model F	0.9141	0.9339	0.9509	0.9452	0.6866	1

Table 5. Robustness Tests

Coefficient	**Model G**	**Model H**	**Model I**	**Model J**
α	0.091***	0.048**	0.129***	0.145***
	(0.026)	(0.022)	(0.026)	(0.025)
β_Y	0.104***	0.117***	0.078***	0.068***
	(0.023)	(0.024)	(0.030)	(0.022)
β_c	0.530***	0.507***	0.462***	0.475***
	(0.103)	(0.087)	(0.142)	(0.085)
β_K	-0.279***	-0.251***	-0.176*	-0.208***
	(0.072)	(0.060)	(0.103)	(0.060)
β_{P_L}	0.426***	0.414***	0.421***	0.425***
	(0.021)	(0.014)	(0.020)	(0.013)
β_t	-0.004***	-0.005***	-0.004*	-0.003*
	(0.001)	(0.001)	(0.003)	(0.002)
β_{Small}	0.247***	0.378***	0.231***	0.179***
	(0.073)	(0.066)	(0.052)	(0.059)
β_{Load}	0.069	0.079**	0.034	0.041
	(0.062)	(0.039)	(0.058)	(0.043)
β_{Dens}	0.047**	0.049***	0.061**	0.065***
	(0.021)	(0.018)	(0.029)	(0.018)
d_{2002}	-0.010	-0.010	-0.013	-0.013
	(0.010)	(0.008)	(0.012)	(0.009)
$\beta_{Lagged\ Comp}$			-0.004	-0.008
			(0.016)	(0.010)
$\beta_{Lagged\ Comp^2}$			-0.026*	-0.028**
			(0.015)	(0.011)
$\beta_{Lagged\ Leaks}$			-0.003	-0.004
			(0.009)	(0.008)
$\beta_{Lagged\ Leaks^2}$			0.015*	0.016*
			(0.009)	(0.010)
ω_{1999}	-2.094***	-2.172***	-1.858***	-1.502**
	(0.708)	(0.627)	(0.667)	(0.697)
ω_{2005}	1.355	2.154	1.223	1.022
	(1.180)	(1.346)	(0.948)	(1.597)
ω_{XD}	3.948		2.402**	
	(3.244)		(1.212)	
ω_{XP}		3.284		3.911
		(3.210)		(5.125)
ω_{u0}	-8.934***	-8.482***	-8.445***	-9.871*
	(3.353)	(3.207)	(1.308)	(5.177)
σ_U^2	-8.777***	-8.825***	-8.776***	-8.716***
	(1.112)	(0.518)	(0.427)	(0.709)
θ	0.062***	-0.055***	0.060***	-0.048***
	(0.005)	(0.005)	(0.008)	(0.005)

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Figure 1. Evolution of Efficiency Estimates