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MONOPOLY REGULATION, CHILEAN STYLE: THE EFFICIENT-FIRM STANDARD IN THEORY AND PRACTICE

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MONOPOLY REGULATION, CHILEAN STYLE:
THE EFFICIENT-FIRM STANDARD IN THEORY AND PRACTICE*

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Abstract

This paper analyses the foundations of "efficient-firm" regulation (implemented in Chile for almost two decades), and the formulas that are used to set the prices of water/sanitation companies, electric power distributors and the dominant phone companies. We show that efficient-firm regulation implies setting prices equal to long-run average cost, which is optimal when the firm is required to be self-financing. In contrast, this is not true of the best-known alternatives, namely regulation based on rate-of-return or a price cap. We also show that in both efficient-firm and price-cap regulation, the fixed and exogenous period that is maintained between price-setting processes stimulates productive efficiency.

We argue that the price-setting formulas and procedures used assume that the regulator has sufficiently precise information to determine the costs of a hypothetical efficient firm, without the need for information from the real firm. Nonetheless, modern regulatory theory and practice both show that prices cannot be set without drawing upon information that only the real firm possesses.

The model developed in this paper is used to discuss the potential gains from replacing efficient-firm regulation by a price cap. We conclude that price-cap regulation also requires considerable amounts of information from the real firm; so, for the time being, Chile should focus on improving regulatory procedures, rather than changing the underlying mechanism.

Key words: Chile, depreciation, electricity, price cap, rate-of-return regulation, sustainability condition, telecoms, water

JEL Classification: L51, L94, L95, L96

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1. INTRODUCTION

The core of public utility regulation in Chile is the concept of "efficient firm" – an hypothetical firm that produces the quantity demanded at the lowest cost that is technically feasible. Although efficient-firm regulation has been used in Chile for nearly 20 years now, there is still considerable controversy surrounding its conceptual underpinnings. For example, during the most recent price-setting processes for telecom and water/sanitation companies, bitter disputes arose between the regulator and the firms on the correct way to include depreciation in the price calculation. This paper presents a simple model that makes it possible to consistently analyze the microeconomic foundations of efficient-firm regulation; it compares this with the best-known alternatives, namely rate of return and price cap regulation; and it analyses the extent to which the actual formulas used to set the prices of water companies, electric power distributors and dominant phone companies correctly reflect the microeconomic principles that underpin them.[1] One of the paper's contributions is to highlight the common structure and foundation underlying public utility regulation in Chile.

The model starts from the sustainability condition that any regulation mechanism should respect, namely that the present value of cash flows generated by the assets invested by the regulated firm should cover the costs of the investment. The peculiarity of efficient-firm regulation is that prices are directly set out of this condition, which means pricing at long-run average cost, bearing in mind the intertemporal nature of the problem. As is well known, this is optimal when the firm is required to self-finance; in addition, however, we show that this condition is very similar to the way prices are determined in competitive markets. The formula used to set prices in each of Chile's public services largely applies this condition, thereby providing a common structure to Chilean monopoly regulation based on sound microeconomic principles.

In contrast, both rate-of-return and price-cap regulation (the best known alternative mechanisms) merely use the sustainability condition as a constraint. Extending the model developed by Newbery (1997), we show that there are multiple price paths that are sustainable, each of which is determined by the time path of accounting depreciation on the authorized assets; only one of these paths is efficient, however. Conceptually, this marks the main difference between efficient-firm regulation and its alternatives. The model also shows that the sustainability condition requires assets to valued on a historical cost basis, regardless of whether regulation is based on rate of return or a price cap. Accordingly, the incentive for overinvestment is very similar in both mechanisms.

[1] Hereinafter the term "water company" will be used to encompass both drinking-water supply and sewerage services.

Although we do not detail the shortcomings of efficient-firm regulation in this paper, our analysis leads us to conclude that these are mainly practical rather than conceptual. They arise from the fact that the formulas and procedures used in setting prices assume that the regulator has sufficiently precise information to determine the costs of the hypothetical efficient firm without the need for data from the real firm itself. Nonetheless, modern regulatory theory, and practice in Chile, show that prices cannot be set without the real firm because information is asymmetric.[2, 3] The model we develop here allows us to analyze what would be gained by replacing efficient-firm regulation with a price cap. Our conclusion is that a price cap also requires considerable information from the real firm, so we suggest that for the time being emphasis should be placed on improving regulatory procedures rather than replacing the mechanism itself. The burden of proof should fall on those who believe the correct course of action is to replace efficient-firm regulation by a price cap.

The remainder of this paper is organized as follows. Section 2 briefly describes the origins of efficient-firm regulation, in order to draw attention to the practical problems that were faced at the time by those who designed the regulations. Section 3 develops a simple model of efficient-firm regulation. Section 4 applies this to evaluate the price-setting formulas used in practice; and section 5 concludes by comparing the price-cap mechanism with efficient-firm regulation.

2. THE ORIGINS OF EFFICIENT-FIRM REGULATION[4]

Efficient-firm regulation was conceived in the early 1980s, largely as a response to three concrete problems faced by public utility firms at that time. Firstly, the electricity and telephone monopolies until then had been regulated on a rate-of-return basis; and the defects of this mechanism were already known, particularly the fact that it stimulates overinvestment and provides little or no incentive to control costs (in fact these shortcomings were mentioned in *El Ladrillo,* the economic plan of the "Chicago Boys"). Secondly, governments in Chile had been setting populist prices since the 1930s at least, which had discouraged private enterprise participation in those sectors and had turned the public firms that took their place into frequent candidates for State subsidies, thereby further weakening any stimulus for efficiency and generating recurrent fiscal problems. Thirdly, the government did not have technical staff capable of regulating their own firms. The fact that the State monopolies were simultaneously producers and

[2] The problem of information asymmetry consists of not being able to regulate without information from the real firm, which the latter has incentives to strategically manipulate in order to obtain prices that approach those of a monopoly.

[3] For example, see Ministerio de Economía (2000), Serra (2000), Tabja (1997), and Galetovic and Sanhueza (2002).

regulators implied a clear conflict of interest.

Several mechanisms were deployed to jointly address these problems. In order to force firms to be efficient and limit their market power, the regulator would set prices according to the costs of a "model" or "efficient" firm, designed from scratch and without considering the real firm. The latter would obtain a normal rate of return only if it was capable of emulating the hypothetical efficient firm; and thereafter the costs of any inefficiency would be borne by the owners of the firm, rather than by users or taxpayers. Although the problem of regulatory discretion and politicization? remained, it was thought this could be overcome by drastically limiting the powers of the regulator through legislation, supported by detailed regulations indicating the methodology to be used to calculate prices, the frequency of the process, and the procedure to be followed in each price-setting episode. At the same time, this detailed legislation based on a fictitious firm would enable the government to regulate its own enterprises, even if the technical staff involved did not wish to cooperate.

This latter point is worth stressing: Chilean regulatory laws were drafted when the immediate problem was that the owner of the firms did not know what the managers were doing - what economists call the "principle-agent problem". Although this problem is very similar to regulating a private firm, there are significant differences. One is that the wealth effects of regulatory decisions, which are central when the firm is privately owned, are much less relevant in the case of state enterprises. The reason is that, subject to well-known provisos, private firms are profit maximizers; in the case of monopolies, each additional peso on the price leads to higher profits. In contrast, the groups who control public firms (e.g. executives, unions, political parties) do not directly benefit from any profits made, since they do not receive them as dividends. The major problem of public enterprises stems from the fact that their controllers obtain most of their benefits through inefficiencies that inflate real costs (e.g. overstaffing, above-market wages for most workers, relaxed working conditions). Accordingly, the incentive facing the controllers of a state enterprise is not to *declare* unrealistically high costs in order to inflate prices, but to incur higher than efficient costs and prevent the existence of an external benchmark that would make it possible to compare them with an efficient standard. In addition to this, in Chile historically the problem had been that prices were set below cost, so one can understand why the emphasis was not placed on reducing information asymmetry but on preventing prices and costs from being *grossly* inefficient.

Application of this model raised the technical standard of regulation to levels hitherto unknown in Chile, and made it possible to privatize the electric power industry and telephone companies in the late 1980s. Nonetheless, the passage of time has revealed that in practice the efficient firm cannot be modeled

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[4] This section is based on Galetovic and Sanhueza (2002).

without data provided by the real firm itself. The problem is, however, that it is the real firm that knows the costs, technology and demand that it faces, not the regulator (i.e. the problem of asymmetric information). Accordingly, although theoretically the benchmark for price-setting is a hypothetical model firm, independent of the real firm, in practice the benchmark is the real firm stripped of its most glaring inefficiencies. It should be noted that this is more or less appropriate when regulating public enterprises, since, as mentioned above, the main problem in this case is gross inefficiency. Nonetheless, the "real firm minus gross inefficiency" is not an appropriate criterion if the firm wishes to inflate its costs in order to achieve higher prices. As the regulatory frameworks introduced during the 1970s and 1980s were based on the premise that the regulator could calculate the relevant parameters of the efficient firm, including demand, without major participation from the real firm, no procedures were established to force the firm to provide quality information.

In sections 3 and 4 we show that the shortcomings of efficient-firm regulation are not conceptual; in fact, we argue that efficient-firm regulation is "optimal" and that the microeconomic concepts underpinning it are consistently applied by the laws governing each sector. Furthermore, the model we develop shows that the price-cap mechanism shares some of the practical problems of regulation based on rate of return, which efficient-firm regulation resolves. This will allow us, in section 5, to put into perspective the suggestion that has insistently been made in Chile, that it would be better to replace efficient-firm regulation by the price cap.

3. THE FUNDAMENTALS OF EFFICIENT-FIRM REGULATION

In this section we develop a simple model that summarizes them and makes it possible to compare efficient-firm regulation with the two most frequently used alternatives, namely rate of return regulation and price cap.[5] The section ends with three applications of the model.

3.1. A simple model

Suppose that to supply $q = Q(p)$ units demanded at a price p requires $K(q)$ units of capital, and involves a constant variable cost of c pesos per unit. The useful life of the capital is T years, after which it becomes useless. If the cost of capital is r, then the net present value of profits generated by an industry that invests $K(q)$ in $t = 0$ is

[5] This model extends that developed by Newbery (1997).

$$NPV_0 \equiv \int_0^T (p_t - c)Q(p_t)e^{-rt}\,dt - K(q). \tag{3.1}$$

Expression (3.1) is simply an accounting identity that is independent of market structure. Nonetheless, it can be turned into a theory if we also indicate how p_t is determined. A particularly relevant case is when $K(q)$ is equal to *kq,* with *k* fixed, and there are constant returns to scale. In this case, the industry will be competitive and in equilibrium

$$NPV_0 = (p - c)\int_0^T e^{-rt}\,dt - k = 0; \tag{3.2}$$

or else, defining $R \equiv \int_0^T e^{-rt}\,dt$ and simplifying,

$$p = c + \frac{k}{R},$$

In other words, price is equal to the long-run average cost, which coincides with marginal cost. The reason for this result is well known, namely that a price set above $c + k/R$ stimulates entry into the industry, whereas if the price falls lower, capital will exit the industry as it comes to the end of its useful life.

The competitive equilibrium satisfies three properties. Firstly, the value of the marginal unit of consumption is equal to the long-run marginal cost, which is known as *allocative efficiency.* Secondly, the good or service is produced at minimum cost, since firms adopt the most efficient technology. This is *productive efficiency.* Thirdly, as can be deduced from condition (3.2), firms exactly cover their long-run economic costs, so they are *sustainable* (i.e. long-run average and marginal costs coincide). It is simple to show that this condition is satisfied for any project, regardless of when it enters the market (see section 3.4).

The regulation of natural monopolies in Chile is based on "emulating competition". Its starting point is the condition

$$Q(p)(p - c)\int_0^T e^{-rt}\,dt - K(q) = 0; \tag{3.3}$$

In other words, in the long run, the price should be such that the firm covers its economic costs, which is the analog of condition (3.2). Nonetheless, there are three differences with regard to a competitive market.

Firstly, if there are economies of scale ($K'q/K>1$) and the price is equal to the long-run marginal cost, then the firm will not cover its costs.[6] The solution in this case is to set p equal to the average cost,

$$p=c+\frac{K(q)}{Q(p)\cdot R}, \tag{3.4}$$

which, as will be seen later, is explicitly recognized by the respective sectoral laws. It can be shown that average-cost pricing is optimal (in other words it is productively and allocatively efficient), subject to the constraint that the firm self-finances. This is also known as the Ramsey-Boiteaux solution.

The second difference with regard to a competitive market is that, to set p, the regulator needs to estimate operating costs *(c),* the cost of capital *(r)* and the cost of investments *(K),* since these are not market-determined quantities. It is at this point that the drafters of the 1982 electric power and telecommunications laws introduced one of their key innovations. Prices should be fixed so as to cover the operating and investment costs of an "efficient" or model firm, rather than those of the real firm.

But what *is* an efficient firm? The most appropriate definition is given in the Telecommunications Act: an efficient firm is one which

> "[...] operates with the costs that are indispensable in providing the services [...] subject to price regulation, efficiently, and in accordance with available technology, and maintaining the quality established for the services in question."[7]

The Electricity Act adds that the efficient firm "[...] operates in the country,"[8] and the Sanitation Act requires account to be taken of "[...] the geographic, demographic and technological constraints under which it is required to operate."[9] In other words, the efficient firm operates at minimum cost with the best technology available at that time, maintaining the service quality standards required by law, but adapting to the properties of geography and demand in each service area. Note that these conditions are precisely

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[6] The total cost of producing q units during T years is $qcR + K(q)$. The marginal cost of an additional unit is therefore,

$$\frac{1}{R}\frac{\partial C}{\partial q}=c+\frac{K'(q)}{R}<c+\frac{K(q)}{qR}$$

if $\frac{K'}{K}q>1$.

[7] Article 30 A and C, Title V, Law 18.168 of 1982.

[8] Articles 294 through 296 of DFL No. 1 of 1982.

[9] Article 27 of DFL No. 70 of 1988.

those of a competitive market: the agent that enters the market (and therefore determines the price) does so with the best available technology, but is constrained by the objective properties of geography and demand.

The third characteristic of efficient-firm regulation is that, as in a competitive market, prices are deduced from a long-run condition – condition (3.3) – which does not depend on the useful life remaining to existing assets at any point in time. Nonetheless, in a competitive market this happens spontaneously because price is determined by the long-run cost that would be incurred by an agent that had sufficient capacity to produce the marginal unit. In a regulated market, on the other hand, this condition has to be imposed by the regulator.

3.2. Asymmetric information, rent extraction and incentives

Strictly speaking, the regulator should design the efficient firm independently of the conditions facing the real firm. But this ignores a basic fact, namely that the firm knows its cost and demand parameters more precisely than the regulator, in other words information is asymmetric. This means that one way or another the regulator must ask the firm for information about the magnitudes of the relevant parameters. There is a clear conflict of interest here, however, since the firm will not wish to admit that its costs are lower or demand higher if this will result in lower prices being set. As can be seen from condition (3.4), the price that is set will be higher, the lower is projected demand, the larger the capital stock required by the efficient firm, the higher its operating costs and the shorter the useful life assumed for the assets. In all cases, it is safe to assume that the firm has more precise information than the regulator. A fundamental result in regulatory theory due to Baron and Myerson (1982) states that it is impossible to completely limit the monopoly power of the firm when information on these parameters is asymmetric. Even if it is regulated optimally, the firm will obtain rents, and the price set will be above long-run average cost.

Secondly, the firm's efficiency does not only depend on the "technology" it uses, but also on how it is run. Better management is more expensive and requires greater effort than bad management, so the level of efficiency will depend on the incentives facing the firm. Nonetheless, if the firm knows that efficiency improvements will be fully passed on through lower prices, it will have no incentive to make an effort to act diligently. In principle, this ought to be resolved if the regulator designs the efficient firm assuming that it is well managed, since the badly managed firm will lose money. But, here again, the regulator depends on the firm for information on what good management consists of – the regulator cannot observe effort and diligence, still less measure them. Laffont and Tirole (1993) have shown that in that case there is a trade-off between limiting the firm's rents (which is usually referred to as "rent extraction") and stimulating it to be productively efficient. Only if the firm keeps a share of the higher profits resulting from better management will it have incentives to be efficient; but this means setting prices above long-run average cost.

Chilean regulatory laws essentially turn a blind eye to the fact that it is impossible to ignore the real firm in practice. Possibly with the exception of the legislation governing water companies, regulatory procedures are grossly inadequate and tend to exacerbate information asymmetries about operation costs, the cost of capital and demand parameters that naturally exist between the firm and the regulator. On the other hand, the legislation is reasonably successful in resolving the problem of stimulating efficient management, because prices are kept fixed for four or five years depending on the sector. Thus, higher profits resulting from productivity improvements achieved during a given pricing period are pocketed by the firm, at least until the following price-setting procedure.

It is usually stated that in Chile incentives to efficiency stem from the fact that prices are set so as to cover the costs of an efficient firm; but this is only partially true. As condition (3.3) shows, the efficient firm is mainly used to bring prices close to long-run average cost and to extract monopoly rents – a task that is impossible to achieve in full when information is asymmetric. The stimulus to efficient management is provided mainly by the fixed and exogenous pricing period. Setting prices so as to finance an efficient firm stimulates efficiency only insofar as the real firm knows that inefficiencies will not be passed on through prices – which is not necessarily the case if the efficient firm ends up being assimilated to the real firm as a result of information asymmetries.

3.3. Efficient-firm regulation compared

There are two alternatives to efficient-firm regulation, namely rate of return and price cap. In this section, we briefly describe these alternatives and compare their strengths and weaknesses.

Rate-of-return regulation. Regulation by rate of return consists of setting prices to ensure the firm earns sufficient revenues to cover observed operating costs and depreciation, and also obtain a return r on the assets invested. The rate of return is usually calculated by weighting the cost of capital and debt, and is set at a "reasonable" level. Prices are typically determined in a two-stage process. Firstly, the revenues needed to cover costs are calculated, which are estimated on the basis of historical information from a recent reference period. In this stage, the regulator holds discussions with the firm to decide which costs are acceptable and how to measure the capital stock to be used as the basis for calculating return. This discussion tends to be highly controversial. In the second stage, the pricing level is set consistently with the revenue needed to obtain the desired rate of return and relative prices between the different regulated services.

To compare this with efficient-firm regulation, it is helpful to start by noting that to guarantee a given rate of return r on assets, the price needs to be set such that

$$p_t Q(p_t) = cQ(p_t) + D_t + rV_t, \qquad (3.5)$$

In other words, revenues must be sufficient to cover operating costs *(cQ),* depreciation *(D_t)* and return on invested capital *(V_t).* As mentioned above, c is obtained by observing the firm's recent costs. D_t is usually obtained from a depreciation rule established in the regulatory contract (e.g. linear depreciation) and V_t is usually obtained from the balance sheet after agreeing which assets are admissible. Accordingly, rate-of-return regulation is based essentially on historical data. Once the values of c, D_t and V_t have been agreed, the price consistent with rate of return r is

$$p_t = c + \frac{D_t + rV_t}{Q(p_t)}. \qquad (3.6)$$

What conditions need to be fulfilled for the firm to be sustainable? Sustainability depends firstly on the relation between D_t and V_t , and secondly on the acquisition cost of the assets, K. Three conditions must be simultaneously fulfilled for the firm's investments to generate a rate of return r throughout their useful life, and for

$$\int_0^T (p_t - c)Q(p_t)e^{-rt}\,dt = K \qquad (3.7)$$

to be fulfilled. (A rigorous demonstration of what follows can be found in appendix A). Firstly, the initial value of the assets recognized for price-setting, V_0, should be equal to their acquisition cost, K; otherwise, part of the invested capital will never earn a return. Secondly, the algebraic sum of depreciation during the useful life of the assets should be equal to their acquisition cost, i.e. $\int_0^T D_t dt = K$. If at the end of their useful life, the assets have not been fully depreciated by the firm, then the prices set according to (3.6) will not generate sufficient revenues to satisfy (3.7). Lastly, the value of the assets used to set the price in t, V_t, must be equal to

$$K - \int_0^T D_t dt,$$

i.e. the initial value of the assets minus the depreciation authorized up to that date.

It might seem that regulation based on rate of return is conceptually very similar to efficient-firm regulation. After all, both have to fulfill a very similar sustainability condition – (3.3) in efficient-firm regulation and (3.7) in the rate-of-return case. Nonetheless, there is a fundamental difference: *Any* depreciation path $(D_t)_0^T$ that satisfies the three conditions described above is consistent with satisfying the requirements that the firm's assets produce a rate of return equal to r.[10] Once this is recognized, it is easy to see that there are multiple price paths p_t, some of which diverge sharply from long-run average cost, but are still consistent with the firm's assets yielding a return of r. In contrast, efficient-firm regulation bases pricing directly on condition (3.3), which forces them to be equal to long-run average costs (naturally this assumes that the regulator correctly estimates the level of the relevant parameters).[11]

A different way to appreciate this point is by analyzing the only case in which they are equivalent. If $D_t = (p-c)Q(p) - rV_t$, with $V_0 = K(q)$ and $V_T = 0$, then the price would be equal to long run average cost $c + K(q)/(Q(p)\cdot R)$. It is easy to show that the firm is sustainable and that the assets yield a return of r throughout. Nonetheless, note that as

$$V_t = (p-c)Q(p)\int_t^T e^{-r(s-t)}dt =$$

$$\frac{(p-c)Q(p)}{r}(e^{-rt} - e^{-rT}),$$

it follows that

$$D_t = (p-c)Q(p)(1 + e^{-rT} - e^{-rt});$$

In other words, the rate of depreciation *rises* over time. In contrast, depreciation rules are usually linear or even accelerated. Accordingly, under ideal information conditions it is unlikely that regulation based on rate of return will produce prices equal to long-run average cost – which is required to achieve allocative efficiency.

The second discrepancy is that in rate-of-return regulation the stimulus to efficient management is

[10] Newbery (1997) deduces a very similar condition, and also observes that there are multiple depreciation paths that satisfy a condition similar to (3.5).

[11] A somewhat surprising implication of this observation is that, once the *arbitrary* depreciation path has been decided upon, this coincides with economic depreciation. The reason is that prices are set to ensure that the rate of return on assets will always be

also different. As discussed in the previous subsection, the fixed and exogenous period between price-setting processes stimulates productive efficiency under efficient-firm regulation, because the firm appropriates the higher profits, at least until the next price review. In contrast, the spirit of rate-of-return regulation is that condition (3.5) is satisfied at all times. Accordingly, the pricing period is neither fixed nor exogenous, and the firm can request a price review whenever it deems costs to have risen. This, together with constraints imposed by asymmetric information, suggests that the stimulus to efficient management is weak, because cost increases (and reductions) are passed on to prices relatively quickly. Accordingly, rate-of-return regulation does not stimulate productive efficiency.

The best-known inefficiency caused by rate-of-return regulation is the incentive to overinvest in capital, which is known as the "Averch-Johnson effect".[12] We know from Baron and Myerson (1982) that the cost of capital rate set by the regulator will tend to be higher than the true rate. And in that case, it suits the firm to raise its capital above the optimal level. Although efficient-firm regulation solves this problem in principle, information is asymmetric in practice. Accordingly, the cost of capital set by the regulator should be higher than the true rate, and the design of the efficient firm also depends partly on what is revealed by the real firm. Once again, how serious this problem is in practice depends on the appropriateness of the regulator's data collection procedures.

The third difference between the two mechanisms concerns procedures. In Chile, the methodology for calculating rate of return and prices is established by law, whereas in other countries (e.g. the United States) the regulator sets a "reasonable" rate of return. In principle, this gives the regulator more discretion, but her power is limited because the rate of return usually forms part of the regulatory contract, and in the end prices have to be consistent with constitutional guarantees that protect against expropriation without due cause.

Price-cap regulation When British Telecom was privatized in 1984, the decision was made to impose an explicit limit on telephone service prices – hence the term price cap or "price ceiling"[13] The origins of the price cap are best understood by seeing it as a substitute for rate-of-return regulation. Its designers were aware that the latter system failed to stimulate productive efficiency. As we have seen, part of the reason for this was that the period between price-setting processes is not fixed, and cost changes are passed on to prices relatively easily. To correct this, the price-cap mechanism was designed with the intention that the period between price-setting processes would be fixed and exogenous (although

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equal to r , given the arbitrary depreciation rule.

[12] See Averch and Johnson (1962).

[13] A detailed description of the price cap is given in Green and Pardina (1999).

in practice in the U.K. the regulator can bring forward the price-setting process if she considers that there is justification for so).[14]

The second difference from rate-of-return regulation is that in principle prices would not be set so as to cover operating costs observed in the recent past, but to generate sufficient revenues to cover projected costs during the pricing period, assuming that the firm is managed efficiently, in addition to generating a given rate of return presumably based on the firm's cost of capital. Delinking prices from effective costs, together with the fixed and exogenous period between price-setting processes, would improve incentives for productive efficiency.

Both the emphasis placed on delinking prices from the costs of the real firm and setting them with reference to an efficient standard, and the fixed and exogenous period between price-setting episodes, makes the price cap similar to efficient-firm regulation. Nonetheless, prices also clearly have to generate a return on capital invested; and, in this dimension, the price-cap mechanism is very similar to regulation by rate of return, because, once r, D_t and V_t are determined, prices are calculated on the basis of a formula such as (3.6); in other words

$$p_t = c + \frac{D_t + rV_t}{Q(p_t)}.$$

Many analysts thought that, as in the case of costs, assets should be valued with reference to their market price, and that this would provide corrective incentives to invest efficiently. Nonetheless, Newbery (1997) showed that it is logically inconsistent to base the price-setting formula on the market value of assets, since ultimately this obviously depends on the price-setting formula decided upon by the regulator. At one extreme, if the market anticipates that the regulator will set low prices, then the firm's assets will be worth little, thereby justifying the low price set by the regulator. At the other extreme, if the market anticipates that the regulator will set high prices, then the assets will be worth a lot, which also justifies the high prices needed to generate an adequate return on those assets. As Newbery (1997) shows, the only way of ensuring sustainability and rent extraction is for the price-setting formula to respect (3.7) and the three conditions indicated above, which is exactly the same as when regulating by rate of return.

Once this has been recognized, it is easy to see that the prices set using the price-cap mechanism will most likely diverge from long-run average cost. As we saw in the previous section, long-run average cost pricing requires depreciation to be rising over time, which contradicts the standard rules of

[14] For example, in 1995, the British electric power regulator unilaterally lowered the price of electric energy distributed by

depreciation. Furthermore, such rules tend to produce high prices when investments have recently been made, and low prices when they are approaching the end of their useful life. Nonetheless, as Newbery (1997) argues, the intensity with which indivisible investments are actually used is precisely the opposite – low (in relation to capacity) just after new investments have been made, but high when the time for reinvesting is approaching, because demand growth requires this. Accordingly, in practice there is a bias towards charging high prices when infrastructure is underused – precisely the opposite to what allocative efficiency requires.

Against this downside, price-cap regulation simplifies calculation of the asset base used to set prices in principle. Recall that sustainability requires that $V_t = K - \int_0^t D_s\,ds$, which means that

$$V_t = V_{t-1} - \int_{t-1}^{t} D_s\,ds,$$

Accordingly, once the depreciation rule is known, it is sufficient to deduct the depreciation authorized during the current pricing period from the assets' accounting value in the previous price-setting process (if there is investment between consecutive pricing rounds, the value of those investments is added to the asset value at the time of the investment, and then depreciation is applied according to the authorized rule). Furthermore, provided the depreciation rules satisfies the three conditions that guarantee sustainability, the real firm can even be allowed to decide its own depreciation scheme. In contrast, efficient-firm regulation requires the value of the assets that the model firm would install to be recalculated each time, which seems more complex.

Nonetheless, the similarity between the price-cap mechanism and regulation by rate of return suggests that the mechanism cannot be so automatic. Bearing in mind the Baron and Myerson (1982) result, the rate of return r used to set prices will also tend to be higher than the true price under the price-cap mechanism. So, the regulator must guard against overinvestment, which makes it inevitable that the procedure must evaluate which assets are necessary and which are not.

The foregoing discussion relates to how the level of prices is set. The price cap introduced three additional innovations in price-setting process. The first of these – obvious in Chile since the 1970s, but a novelty in developed countries – consisted of authorizing the firm to index fixed nominal prices to variations in the consumer price index CPI (or the *retail price index,* RPI, in the UK). The second consisted of recognizing that part of the productivity increases achieved in regulated firms corresponds to

between 11% and 17%, and then again by a further 10%-13% in 1996. See Westlake and Beckett (1995).

improvements that do not depend on the firm's own efforts, but are exogenous. For example, data-processing costs depend on the rate of technological process in the computer industry, which has little or nothing to do with what the regulated firm does. Retaining larger profits by definition does not stimulate productive efficiency, so prices could be reduced immediately. In this way, prices would vary exogenously by (ΔCPI -*x*)/100 every period, where x is the estimated exogenous rate of productivity growth. This innovation speeds up rent extraction, and is soundly based on the theory of regulation by incentives. On the other hand, it raises the problem of how to calculate the *x factor,* which has caused several controversies.

The third innovation consisted of imposing a limit on an index of the cost of a basket of services, rather than on each service individually. The firm is allowed to set the price of each service provided the overall index does not exceed the limit, thereby relieving the regulator of the complicated task of setting relative prices, and allowing the firm to adjust these to changing demand conditions. In this way, the limit behaves according to

$$\sum_{i=1}^{n} \lambda_i p_{it} = \left[1 + \frac{\Delta IPC_{t-1} - x}{100}\right] \cdot \sum_{i=1}^{n} \lambda_i p_{it-1}, \tag{3.8}$$

where λ_i is the share of each service in the basket comprising the index (with $\sum_i \lambda_i = 1$), and p_{it} is the price of service i set by the firm in period t.

The main advantage of setting limits on a basket rather than on each individual price is that the regulator does not have to worry about estimating correct relative prices. In addition, the firm is given flexibility to adapt relative prices between price-setting rounds, which is beneficial since demand conditions usually alter in the interim. The downside is that the firm could take strategic advantage of errors made by the regulator in setting the λ_i. For example, if the real share of a given service is much less than that set by the regulator, the firm could lower its price and raise that of other services, thereby raising the price of the effective basket above the level intended by the regulator.

3.4. Applications

The model we have developed makes it possible to study several issues that frequently give rise to dispute. Here we use it to discuss the treatment of obsolescence and depreciation, and to show that the economic profitability of assets regulated on an efficient-firm basis is always r, regardless of the frequency of price-setting processes.

Risk of obsolescence A particularly important topic in regulation is the treatment of asset obsolescence *(i.e. stranded assets).* In Chile, the three laws that mention the efficient firm state that this incorporates the best current technology. This means that the risk of obsolescence must be borne by the regulated firm, just as it would be in a competitive market with free entry. Nonetheless, we shall see below that sustainability requires this risk transfer to be compensated by a higher discount rate, as also happens in a competitive market.

To model this problem, suppose that in *t* the density function of the date of the asset's technical (but not physical) obsolescence is $f\ (s - t)$. Then $F(s-t)=\int_t^s f(u-t)du$ is the probability that the asset becomes technically obsolete in at least $s - t$ years. Note that we assume the process has no memory; for example, the likelihood of the asset becoming obsolete during the next four years is independent of *t.* In addition, and solely for the purpose of simplifying the exposition, we also assume that, once obsolete, the best policy is to offload the asset immediately and replace it with the most efficient substitute.[15]

The expected present value of our asset when prices are set in $t = 0$ is now

$$NPV_0=\int_0^T f(t)\int_0^t (p_s-c)Q(p_s)e^{-rs}dsdt+[1-F(T)]\int_0^T (p_t-c)Q(p_t)e^{-rt}dt.$$

Note that $f(t)$ is the probability that the asset becomes obsolete in *t,* in which case the present value of the flows delivered by the asset will would be $\int_0^t (p_s-c)Q(p_s)e^{-rs}ds$. On the other hand, $1 - F(T)$ is the probability that the asset does not become obsolete before completing its physical life; in which case flows would be equal to $\int_0^T (p_t-c)Q(p_t)e^{-rt}dt$, as in the case where there is no risk of obsolescence. Sustainability now requires setting prices such that

$$(p-c)Q(p)\left\{\int_0^T f(t)\int_0^t e^{-rs}dsdt+[1-F(T)]\int_0^T e^{-rt}dt\right\}=K.$$

Noting that $\int_0^T f(t)\int_0^t e^{-rs}dsdt=\int_0^T e^{-rt}\int_t^T f(s)dsdt$, and after a little algebra, this condition can be rewritten as

[15] Broadly speaking, for this to be true, the saving in terms of variable costs needs to outweigh the cost of bringing forward the investment in new technology.

$$(p-c)Q(p)\int_0^T [1-F(t)]e^{-rt}\,dt = K. \tag{3.9}$$

Condition (3.9) is very similar to (3.3), except that the term *F(t)* increases the discount and consequently the equivalent rate. The discount rises with *T* because the asset is more likely to become obsolete in five years rather than in three. All of this means that shifting the risk on to the firm requires it to be compensated through higher prices until the asset becomes obsolete.[16] Nonetheless, it is not easy to do this with precision, since it requires estimating *F(t)*.

A graphic case is when the asset becomes obsolete according to an exponential process with a density function $f(t) = \pi e^{-\pi t}$. In that case, $1 - F(t) = e^{-\pi t}$ and (3.9) can be rewritten as

$$(p-c)Q(p)\int_0^T e^{-(r+\pi)t}\,dt = K,$$

where π represents the risk premium.

Efficient-firm regulation differs from regulation by rate of return in the way it treats obsolescence. For example, in the United States, the regulatory contract and constitutional guarantees that protect against expropriation without fair compensation shift the risk of obsolescence on to consumers. In that case, the correct condition for calculating prices remains (3.7).

Depreciation and taxes So far we have ignored depreciation and taxes. Tax depreciation is important because it affects the firm's after tax profitability. Similarly, the fact that firms can deduct interest paid on debt as an expense, but not the return required by capital, means that post-tax profit will depend on the firm's debt-equity gearing (a subject that we do not address here).

To analyze the consequences of depreciation we assume the firm is financed entirely with equity (i.e. there is no interest deduction). If the authorized tax depreciation is $(D_t^I)_{t=0}^T$ (the superscript *I* denotes "taxes"), then the present value of our asset is

$$\int_0^T \left\{(1-\tau)\left[Q(p)(p-c) - D_t^I\right] + D_t^I\right\} e^{-r(1-\tau)t}\,dt - K, \tag{3.10}$$

Where τ is the tax on profits. Obviously, taxes reduce the firm's net cash flow, but the magnitude of this

[16] Is important to note that if it remains worthwhile to continue using technically obsolete assets until the end of their useful physical life, then expression (3.9) exaggerates the premium, because flows generated between the moment of technical obsolescence and the end of their physical useful life will not be zero.

effect depends on the depreciation allowed by the tax law, since tax depreciation, which is not a cash flow, is accepted as an expense and therefore reduces the tax liability. In addition, taxes also require adjustment of the rate of return used to discount the flows: the after-tax rate of return should be used since this is what represents the alternative cost of investing one peso in the regulated sector.

Defining $r' \equiv r(1-\tau)$ the after-tax rate of return, expression (3.10) can be rewritten as

$$(1-\tau)Q(p)(p-c)R(r') + \tau\int_0^T D_t^I e^{-r't}dt - K.$$

To extract all the monopoly rents, we require that

$$pQ(p)R(r') = \frac{K}{(1-\tau)} + cQ(p)R(r') - \frac{\tau}{(1-\tau)}\int_0^T D_t^I e^{-r't}dt. \tag{3.11}$$

As we shall see below, this formula is actually used to set prices in the drinking water and telecom sectors, although, to be consistent, the after-tax rate of return $r(1 - \tau)$ should be used.

Expression (3.11) highlights the importance of distinguishing between the useful life of the asset *(T)* and the depreciation rule used, $(D_t^I)_{t=0}^T$. An asset's useful life determines the period in which it generates cash flows. In contrast, its useful tax life depends on the depreciation rule $(D_t^I)_{t=0}^T$ used, which does not necessarily coincide with its economically useful life, and obviously does not determine the period in which the asset generates cash flows. Accordingly, price-setting should always use the economically useful life; the term $\int_0^T D_t^I e^{-r't}dt$ fully incorporates the effect of tax depreciation on cash flows.

It could be argued that by considering taxes and including tax depreciation, one is abandoning optimal pricing – after all, the social opportunity cost of the capital in the example is r and not $r(1-\tau)$; and tax depreciation does not represent an opportunity cost. But here one needs to remember that average-cost pricing is optimal subject to the firm's self-financing constraint. Condition (3.11) only extends that constraint to the case where the firm pays taxes, recognizing that the tax and depreciation regime is an additional constraint in the regulatory process.[17]

The useful life of assets and the duration of pricing periods. One of the key features of efficient-

[17] The reader will surely note that the firm's shareholders pay taxes. In Bustos, Engel and Galetovic (2004) we showed that characteristics of the Chilean tax system mean that the tax rate that should be corrected to take account of this is *Primera Categoría* (first category) tax, paid by firms.

firm regulation is that it provides an economic rate of return of r to the firm's assets at all times, regardless of the frequency or timeliness of price setting. To appreciate this, note that by definition the economic rate of return of a regulated asset in t is

$$\frac{(p-c)Q(p)-D_t^e}{V_t^e}, \tag{3.12}$$

where D_t^e is the economic depreciation of the asset in t and V_t^e is its economic value. If regulation is based on the efficient firm, the value in t of an asset whose useful life is T years and was invested in $t = 0$ is

$$V_t^e = (p-c)Q(p)\int_0^T e^{-(s-t)}ds,$$

where p is such that $V_0^e = K$. Differentiating V_t^e with respect to t gives

$$\frac{\partial V_t^e}{\partial t} = -D_t^e = -(p-c)Q(p) + rV_t^e,$$

Substituting in (3.12) we have

$$\frac{(p-c)Q(p)-D_t^e}{V_t^e} = \frac{rV_t^e}{V_t^e} = r, \tag{3.13}$$

which is independent of t, and of the useful life remaining to the asset *(T - t* in this example), and also of the time at which p is set. Note too, that the benchmark for calculating prices is K*;* at no time is it necessary to determine the economic value of the existing assets.

4. EFFICIENT-FIRM REGULATION IN PRACTICE

In this section we review the formulas used to set prices in each of the three regulated sectors. In each sector we study the extent to which specific price-setting rules put these principles into practice.

The prices charged by each of the three monopolies are established in price-setting rounds.[18] These

[18] These are described in Galetovic and Sanhueza (2002).

are governed by laws and their respective regulations, but in each case technical-economic ground rules are prepared which indicate how to adapt the rules to the circumstances of each price-setting process. What follows is based on the ground rules for price-setting in the phone company CTC (during the period 1999-2004); the water utility EMOS (for the period 2000-2005); and electric power distributors (for the period 2000-2004).

4.1. General considerations

4.1.1. Concept

Prices are calculated in two stages. The outcome of the first stage yields *efficient prices.* In telecom and water companies, these are calculated to ensure that expansion projects are self-financing and give a net present value (NPV) equal to zero. Formally, the price is such that

$$(p^e - c)\Delta Q \int_0^T e^{-rt} dt - \Delta K = 0, \tag{4.1}$$

where ΔQ is the estimated variation in demand, and ΔK is the investment needed to satisfy this (of course, we are ignoring taxes here to simplify the exposition).

Nonetheless, if there are economies of scale, these prices would not be sufficient to self-finance the whole firm, in other words, what is desirable is that

$$(p^e - c)\Delta Q \int_0^T e^{-rt} dt - (K_0 + \Delta K) < 0$$

(Q_0 is the initial level of demand and K_0 is the capital stock of an efficient firm designed to satisfy demand at the level Q_0*).* If this occurred, efficient prices are corrected in the second stage, in principle in the least distorting way possible, to enable the efficient firm to *fully* self-finance, in other words

$$(p^d - c)(Q_0 + \Delta Q) \int_0^T e^{-rt} dt - (K_0 + \Delta K) = 0 \tag{4.2}$$

p^d is referred to as the *definitive price.*

Note that efficient prices correspond to the average but *incremental* cost. If the expansion alone had to be priced, these would be efficient prices subject to the firm's self-financing constraint. Efficient prices are corrected in the second stage only if they are insufficient to self-finance the efficient firm, which means that allocative efficiency is prioritized ahead of rent extraction.

4.1.2. The pricing area

Once the rationale and concepts underlying Chilean monopoly regulation are understood, it is easy to understand the difference between efficient and definitive prices. Nonetheless, these concepts have no content until their variables and parameters are measured when setting prices. Equations (4.1) and (4.2) are also useful for describing what the regulators need to specify to give content to the technical-economic ground rules. These specifications can be grouped into three categories:

(i) the production technology with which the efficient firm will produce the regulated services (the production function);

(ii) the price of inputs and the cost of the assets needed to construct the efficient firm;

(iii) and the estimated demand for the regulated services.

Given the cost-minimization assumption, the first two categories determine the cost function of the efficient firm; in our equations, these are represented by the function K and the parameters T and c. Knowledge of demand is needed because efficient average costs depend on the scale of production (K is a function of q).

Obviously, to determine (i)-(iii) one needs to know what services need to be regulated; but this is known when the ground rules are drawn up. The key aspect of the ground rules is that they define the pricing areas (or *typical areas)* that each efficient firm is required to serve. The service has the same price throughout a given pricing area, by definition. But in reality, uniform prices should be a consequence of the fact that the average cost of providing the service is the same throughout the area. Accordingly, although the criterion for defining the area may be geographic, technical or demographic, the idea is that it should be defined by the main determinants of the cost of providing the service; and differences in these key determinants define different areas.

For example, the most important variable in electric power distribution is the number of customers per km^2, or density. A given concession-holder serving a continuous area (e.g. Chilectra) might have different pricing areas, if density is much greater in some geographic zones than in others; and two distributor firms can have the same pricing areas if they have similarly densities. By contrast, in the case of water companies, the basic concept is that of the “system”, as defined in the corresponding law

> “[...] installations, sources or receptor bodies and other elements, feasible of interacting, associated with the various stages of the water/sanitation service,

which should be considered as a whole, in order to minimize the long-run costs of providing the water/sanitation service."

[emphasis added]

In that case, the criterion is geological, and each real firm tends to be different (unless they share the same system).

4.2. The sectors

4.2.1. Telephony

Prices are set for 29 telephone services, 23 of which are classified explicitly by the Antitrust Resolutory Commission, and six by law.[19] In the most recent price-setting round, four pricing areas were defined.

The pricing study is conducted by the regulated firm, and then the regulator makes observations on it (for further details see Galetovic and Sanhueza 2002, and especially Tabja 1997). The starting point involves projecting the demand for each of the regulated services in each pricing area over the next five years. Once demand has been projected, an efficient firm is designed which incurs the costs that are essential in providing the regulated services alone.

If there is an expansion project, its *incremental development costs* are calculated, together with the revenues needed for the project's NPV to be equal to zero – given investment and operating costs, the useful life of the assets associated with the expansion, the tax rate on profits and the cost of capital. Formally,

$$\frac{1}{1-\tau}\left[\sum_{t=1}^{5}\frac{I_t}{(1+r)^t}+\sum_{t=1}^{5}\frac{(1-\tau)\Delta C_t-\tau D_t}{(1+r)^t}-\frac{(\text{residual value})_{t=5}}{(1+\text{r})^5}\right], \tag{4.3}$$

where I_t is the investment in t and ΔC_t is the increase in total costs in t associated with the expansion project. The efficient price for the respective service is obtained from the equality

[19] The most important of these are local calls between users of the same company (the local metered service - LMS); access charges paid to use the local network in long-distance calls, or calls to a mobile phone; and the access charge paid when a subscriber from another local company calls a CTC subscriber (in Chile there is more than one local company serving most cities).

$$p^e \cdot \sum_{t=1}^{5} \frac{\Delta q_t}{(1+r)^t} = \frac{1}{1-\tau}\left[\sum_{t=1}^{5} \frac{I_t}{(1+r)^t} + \sum_{t=1}^{5} \frac{(1-\tau)\Delta C_t - \tau D_t}{(1+r)^t} - \frac{(\text{residual value})_{t=5}}{(1+\mathrm{r})^5}\right],$$

where Δq denotes the change in demand for the service that satisfies the expansion project.

Definitive prices are determined with an expression analogous to (4.3). The scale of the efficient firm is designed to optimally satisfy total average demand projected during the pricing period (the next five years), which is known as "equivalent demand" and denoted by q^*. If efficient prices cover these costs, then they are definitive. Otherwise, the prices of each service must be adjusted until total projected revenues coincide with the total cost of the efficient firm designed to serve q^*. The law is silent on how the adjustment between the different services should be shared out, apart from stating that "any inefficiencies introduced should be kept to a minimum."

Expression (4.3) is formally very similar to the right-hand side of (3.11) which we repeat here for convenience with a number of minor modifications,

$$\frac{\Delta K}{(1-\tau)} + \int_0^T c\Delta Q e^{-rt}\, dt - \frac{\tau}{(1-\tau)}\int_0^T D_t\, e^{-r't}\, dt,$$

except that in practice time is discrete. Expression (3.11) can be rewritten as

$$\frac{1}{1-\tau}\left\{\frac{\Delta K}{(1-\tau)} + \int_0^5 \left[(1-\tau)c\Delta Q - \tau D_t\right] e^{-rt}\, dt + e^{-r5}\,(\text{residual value})_{t=5}\right\},$$

(4.4)

where $(\text{residual value})_{t=5} \equiv c\Delta Q\int_5^T e^{-r(t-5)}dt - \tau\int_5^T D_t e^{-r(t-5)}dt$, and clearly $\Delta K \equiv \sum_{t=1}^{5} \frac{I_t}{(1+r)^t}$.

Accordingly, price-setting for telephone services correctly applies the principles of efficient-firm regulation, since r is the *after-tax* rate of return, depreciation corresponds to tax depreciation, and the residual value of the assets is correctly calculated, which requires appropriate estimation of its useful economic and physical life.

The cost of capital rate used in practice is obtained from the expression

$$r = r_f + \beta \times (\text{market risk premium})$$

where r_f is equal to the rate paid on a savings account with deferred withdrawals at the Banco del Estado de Chile [20] and β is the covariance of the return earned by the firm relative to the market portfolio. In any event, r cannot fall below 7%.

Needless to say, the calculation of *beta* and the risk premium have led to major disputes in price-setting processes (see for example Ahumada 2000). Here we will only mention that this criterion for determining the cost of capital rate is largely circular, because much of the firm's specific risk depends on the rule used in setting its prices.[21] In this regard, using international *betas* is not the most appropriate policy, since they are obtained from industries that are regulated with various rules. Nonetheless, in principle the cost of capital of the efficient firm should clearly be equal to the market rate.

4.2.2. Drinking water supply

Each stage of the water/sanitation service is priced: i.e. captation of untreated water, production of potable water and its distribution, collection of wastewater and disposal thereof.[22,23] Price-setting is done per firm and each pricing area corresponds to a *system*.[24] The aim of defining a system is to arrange the installations of the efficient firm so as to satisfy projected demand at minimum cost.

Unlike the telephone case, both the firm and regulator conduct a pricing study, with discrepancies being resolved by binding arbitration (for further details see Medina 2000 or Galetovic and Sanhueza 2002). The study starts with a demand projection for the next 15 years (after the 15th year it is assumed that demand grows no further). This distinguishes between periods of peak consumption (which typically coincide with the summer months), and periods of lower "off-peak" consumption. An efficient firm is then designed. As in the telephone case, the incremental development costs of any expansion project are calculated.[25] The formal expression in this case is

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[20] Or, if this disappears, the rate payable on the replacement instrument indicated by the Superintendency of Banks and Financial Institutions.

[21] On this point, see Ian and Irwin (1996).

[22] The Ministry of Economic Affairs also establishes what can be charged for other services such as disconnection and reconnection of users in arrears, maintenance of public and private standpipes, direct control of liquid industrial waste (LIW) and a review of engineering projects for LIW treatment systems.

[23] For further details on regulation of the sector see the collection of articles edited by Oxman and Oxer (2000). Gómez-Lobo and Vargas (2001) make a detailed analysis of recent EMOS price-setting processes and also explain the rationale behind regulation of the sector.

[24] A "system" consists of installations in the different stages of the sanitation service that can physically interact, and which should be jointly optimized to minimize the long-run costs of providing the service. Note that to apply this definition, one needs to know the distribution of consumption.

[25] If there is no expansion project, long-run marginal costs are calculated.

$$\frac{1}{1-\tau}\left[\sum_{t=1}^{35}\frac{I_t}{(1+r)^t}+\sum_{t=1}^{35}\frac{(1-\tau)\Delta C_t-\tau D_t}{(1+r)^t}-\frac{(\text{residual value})_{t=35}}{(1+\mathrm{r})^{35}}\right]. \tag{4.5}$$

Note that unlike the telephone sector, the evaluation horizon, 35 years, does not coincide with the duration of the pricing period (five years in the case of water companies). Furthermore, although we do not go into details here, investment earns a return only from the fees paid by users that consume water during the peak period. Nonetheless, similar reasoning to the telephone case indicates that expression (4.5) is formally equivalent to the right-hand side of (3.11), thereby revealing the common structure of regulation in both sectors.

The sustainability check is very similar to that in the telephone sector. The scale of the efficient firm is designed to optimally satisfy equivalent demand. This is equal to

$$q^* = r\frac{(1+r)^5}{(1+r)^5-1}\cdot\sum_{t=1}^{5}\frac{q_t}{(1+r)^t}.$$

Once this firm has been designed, the long-run total costs of satisfying projected demand are calculated in setting efficient prices. If efficient prices cover these costs, then they are definitive. Otherwise, each charge is adjusted proportionately until projected revenues coincide with the total cost of the efficient firm designed to satisfy q^*.

Unlike the telephony case, here the law does indicate how to adjust efficient prices. Note that the uniform adjustment required means going against Ramsey pricing, which recommends charging the difference by making adjustments in amounts inversely proportional to the elasticity of demand – which in this case probably would mean raising fixed charges relatively more (see appendix B).

4.2.3. Electric-power distribution

The regulation of distribution charges in the electric power sector displays significant differences in comparison to the telephone and water cases.[26] The most important of these is that regulation applies to the entire set of distributors, since the key determinant of costs is customer density in the service area, and not the scale of production.[27] The basic premise is that two distributors that serve areas of similar density

[26] On the regulation of electric power distribution, see Bernstein (2000), Briant (2000), Molina (1998), Rudnick and Donoso (2000), and Rudnick and Raineri (1997).

[27] The most commonly used measurements of density (or density parameters) are the ratios between (i) peak demand in the system and the number of kilometers in the distribution network; (ii) the number of clients connected to the network and the number of kilometers in the distribution network; (iii) the number of urban homes in relation to the total surface area served by

should have similar costs, even though the sizes of their firms may be very different.[28] In other words, once adjusted for density, returns to scale in electric power distribution should be constant.

In this way, pricing areas (which in this case are referred to as "typical areas") are defined by their density.[29] For each typical area, a geographic zone is selected from one of the real firms that represent it. For that geographic zone, an efficient firm is designed adapted to demand. The results are then applied to the geographic zones of other firms with similar densities.[30] The regulator (in this case the National Energy Commission) and the firms commission separate pricing studies from consultants, and a weighted average of the results is calculated, in which the study commissioned by the regulator has a two-thirds weighting.

Distribution prices, also known as *value added in distribution (*VAD) transfer three types of cost to users: fixed costs, mainly covering administration of the distribution firms; the cost of losses of energy and power transmitted by the lines, including theft;[31] and the cost of investment, operation and maintenance of the infrastructure needed to distribute the electricity. In each case, a distinction is made between high-voltage users (connected at over 23 KV) and low-voltage consumers. In this section, we are particularly interested in the third item, namely the calculation of infrastructure costs.

As mentioned above, infrastructure corresponds to that of an efficient firm adapted to demand in the geographic zone of the real firm used to define the typical area, assuming that installations have a 30-year useful life. The formula in this case is

$$\frac{1}{K}\cdot\left[K_0+\sum_{t=1}^{30}\frac{(\text{operation and mantenaince costs})_t}{(1+0.1)^t}\right], \tag{4.6}$$

where KW is the maximum demand faced by the real firm, and K_0 is the value of the infrastructure of the

the distributor; and (iv) electric energy sold to regulated customers in relation to the number of inhabitants. See Bernstein (2000).

[28] For evidence on this point see Bernstein (2000, pp. 43 and 44).

[29] In the 1996 pricing study, five standard areas were defined. See Molina (1998, pp. 85-87) for further details.

[30] This criterion was altered in the 2000 price-setting round. Six standard areas were defined, and each real firm was assigned to one of these.

[31] *Instantaneous power* is the capacity to do mechanical work, and is measured in watts (W). *Energy* measures the use of instantaneous power in a given time period, and is measured in watts per hour or watt-hours (Wh). Thus, for example, a 100 watt light bulb consumes 50 Wh if it is on for half an hour. One kilowatt hour (kWh) is equal to 1000 Wh; a megawatt-hour is equal to 1000 kWh; and a gigawatt hour is equal to 1,000 MWh. Electricity charges cover energy and *maximum power;* the latter corresponds to the maximum value attained by instantaneous power in a given period of time. This power determines the scale or capacity of installations needed to supply it. Accordingly, the terms "power payment" and "capacity payment" are often used indistinguishably.

efficient firm designed to satisfy demand in the base year, valued at the cost that the firm would have to pay to acquire it outright.[32] Clearly this expression is very similar to those used to set efficient prices in the telephony and water sectors, but it differs by not calculating the cost of an expansion project, but directly calculates the average costs of the efficient firm. This simplification is consistent with the premise that returns to scale in distribution are constant once adjustment has been made for density. In this case, marginal and average costs coincide, and there is no need to calculate efficient prices.

The second difference is that the profitability of the efficient firm is not calculated, since the law sets this at 10%, which could lead to gross overestimates of the cost of capital, should the long-term interest rate in Chile fall. It is preferable for the discount rate to be tied to the risk-free interest rate, in order to reflect variations therein over time.[33] Lastly, the formula does not consider tax depreciation. Although this is consistent with calculating pre-tax profitability, the discussion in section 3.4 shows that the tax saving arising from depreciation reduces the revenues needed to enable to firm to self-finance.

The result of these calculations provides the basic prices for each typical area, which should cover fixed costs, energy and power losses, and the costs of construction, operation and maintenance of infrastructure.[34] Once calculated, a profitability check is carried out. Unlike price-setting in the drinking water and telephony sectors, sustainability is not measured in relation to the efficient firm (this was done in the previous stage when calculating long-run average cost), but with respect to the set of real firms.

Before designing the efficient firm, real firms value their installations at their new replacement value (NRV), in other words the cost of replacing existing installations (definitive values are established after the Superintendency of Electricity and Fuels has reviewed the amounts declared by each firm, and any discrepancies are resolved through arbitration).[35] In addition, firms report their operating costs. These NRVs and costs are then used to calculate the profitability which the set of firms would have obtained if the energy and power consumed during the year preceding the price-setting round had been sold at basic prices for 30 years. Formally, if firm *i* declared NRV_i , and operating costs are denoted by c_i, its sales are q_i and the corresponding basic price is p_i, then the profitability of the set of firms is

[32] A distinction is made between high- and low-voltage users.

[33] One often hears comments on the "error" supposedly committed by the people that drafted the electric power law by setting a fixed rate. Nonetheless, this criticism takes no account of the context in which the law was drafted – particularly that, at that time, the aim was to regulate public enterprises. Not surprisingly, 10% is the social rate used at that time by the planning Ministry the only long–run interest rate.

[34] For further details see Molina (1998).

[35] The NRV differs from replacement cost, since it represents the economic opportunity cost of replacing existing installations today to provide the same service. It therefore assumes that installations are replaced with the most efficient technology currently available. Replacement cost, on the other hand, is the cost of constructing existing installations today, regardless of

$$r = \frac{\sum_i p_i q_i - c_i}{\sum_i NRV_i} = \sum_i \alpha_i r_i ,$$

where $\alpha_i = NRV_i \Big/ \sum_j NRV_j$ (all of this is measured before tax). If r is between 6% and 14% then the basic prices are definitive. If profitability falls outside this range, however, prices are adjusted proportionately until they reach the nearest limit.[36]

It has been argued that the profitability check to some extent obliges firms to compete on the basis of comparison (i.e. yardstick competition).[37] For example, if the r_i of a small firm was considerably lower than the average, this would not have much effect on prices, and the firm would have to assume the costs of its inefficiency. Nonetheless, in principle basic prices are fixed according to the costs of an efficient firm, so the second stage does not add much. Another shortcoming of the second stage is that the outcome of the exercise depends heavily on the results of Chilectra, whose NRV accounts for over 45% of the total.

5. CONCLUSION: PRICE CAP OR EFFICIENT-FIRM REGULATION?

It is a cliché that there is no perfect regulation mechanism; nonetheless some mechanisms are better than others. Efficient-firm regulation has significant virtues: it is optimal subject to the firm's self-financing constraint – a property that is not true of the main alternatives, namely regulation based on rate of return and the price cap. Furthermore, fixed pricing periods stimulate efficient management in a similar way to price-cap regulation, which in turn, is clearly superior in this regard to regulation based upon rate of return. Thirdly, it clearly shows, although only in principle, how to determine which assets should be included in the regulatory asset base and which not, which is not true of price-cap or rate-of-return regulation.[38] Lastly, the conceptual clarity of efficient-firm regulation allows a lot to be expressed in writing, in laws and regulations. As price-cap and rate-of-return regulation have both been developed in countries with legal traditions that are much more effective than Chile's in terms of legally restricting the undesirable consequences of regulatory discretion, they would seem less appropriate for Chile than a

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whether they are obsolete or not. See the discussion in Rudnick and Raineri (1997).

[36] In addition, the profitability of the set of firms in each year subsequent to the price-setting round should be between 5% and 15%. The Electricity Regulation of September 1998, allows the NEC to cancel prices in advance, and start a new pricing period, if measured profitability falls outside the band.

[37] See the discussion in Rudnick and Donoso (2000), and Rudnick and Raineri (1997).

[38] On this point, see the discussion in Newbery (1997).

legalistic approach to regulation.

Nonetheless, several studies suggest that efficient-firm regulation has not been sufficiently effective in extracting rents from regulated firms once they have been privatized.[39] We suggest this is because the procedures used are unsuitable for extracting reliable information on technology, costs and demand from the regulated firms: there are no systematic and continuous data collection mechanisms, and each price-setting round starts by redesigning the efficient firm from scratch, without making much use of lessons learned from previous price-setting processes. Although it is well-known that asymmetric information results in prices being set above long-run average cost, in Chile, the difference is likely to be larger than justifiable.

It has also been argued that the intensity of asymmetry could be moderated by replacing efficient-firm regulation by a price cap*,* where it would not be necessary to redesign the efficient firm every time prices were set. Nonetheless, we have shown in this paper that the price-cap mechanism requires assets to be valued at historic cost, which stimulates overinvestment and gold plating just as in the case regulation by rate of return. Accordingly, the price-cap mechanism cannot be applied without giving the regulator the power to veto "unnecessary" investments and expenses. The purpose of efficient-firm regulation is precisely to determine which assets and expenses are necessary (or efficient). The advantages over the price cap are that the conceptual criterion for carrying out this exercise is very clear, and is now institutionalized in Chile. Its disadvantage is that regulation on an efficient-firm basis requires each price-setting round to decide upon the admissible value of the assets of the firm as a whole and not just the new investments.

Clearly, the arguments of the previous paragraph are not sufficient to rule out the price-cap alternative; but nor do we think it is clearly advisable to abandon efficient-firm regulation. To decide on a reasoned basis whether it is advisable to adopt the price cap, it would firstly be necessary to perform a detailed study of the extent to which it would reduce the need to obtain information from the true firm;[40] and secondly to design suitable procedures and rules to determine which expenses and investments are admissible, while at the same time respecting the constraints imposed by Chile's institutions and legal system. If changing the regulation mechanism made it possible to significantly reduce information asymmetries and improve the possibilities for rent extraction, then the price cap should be considered as an alternative to efficient-firm regulation, despite this meaning the abandonment of (efficient) pricing at

[39] See for example Serra (2000).

[40] A "detailed study" means characterizing the sources of information asymmetries in each sector, and then gauging the extent to which the price-cap mechanism would reduce the need to obtain detailed information in order to regulate.

long-run average cost. Nonetheless, the price-cap mechanism would also clearly require substantial improvements in procedures, because it cannot be applied without information from the real firm.[41] Given that a change of regulatory mechanism would also face a series of legal obstacles – among other things because it would require changes to existing contracts – in our opinion the emphasis during the next few years should be placed on significantly improving procedures for data collection and fine-tuning price-setting formulas, rather than replacing efficient-firm regulation as a whole. The burden of proof should fall on those who believe that price-setting rules ought to be changed.

[41] On this point see Green (1997a and b).

Appendix

A. RATE OF RETURN REGULATION AND SUSTAINABILITY

The text states that the following conditions must be satisfied simultaneously to ensure that the assets of a firm regulated on a rate-of-return basis according to

$$p_i Q(p_t) = cQ(p_t) + D_t + rV_t \tag{A.1}$$

yield r: (i) $V_0 = K$; (ii) $\int_0^T D_t dt = V_0$; (iii) $V_t = K - \int_0^t D_s ds.$ We show this below.

Consider any path $(V_t, D_t)_0^T$ for depreciation that satisfies (A.1) and condition (iii). In that case, the present value of the asset in $t = 0$ is

$$\int_0^T (p_t - c)Q(p_t)e^{-rt} dt = \int_0^T \left[D_t + r\left(V_0 - \int_0^t D_s ds \right) \right] e^{-rt} dt.$$

The right-hand side of this equality can be rewritten as

$$rV_0 \int_0^T e^{-rt} dt + \int_0^T D_t \left[e^{-rt} - r\int_t^T e^{-rs} ds \right] dt$$

$$= V_0(1 - e^{-rT}) + \int_0^T D_t \left[e^{-rt} + e^{-rT} - e^{rt} \right] dt$$

$$= V_0(1 - e^{-rT}) + e^{-rT} \int_0^T D_t dt.$$

If condition (ii) is fulfilled, then $\int_0^T D_t dt = V_0$ and

$$\int_0^T (p_t - c)Q(p_t)e^{-rt} = V_0 = K,$$

where the latter equality follows from condition (i).

B. DRINKING WATER CHARGES

This appendix illustrates calculation of the pricing structure for drinking water. The aim is to give a clear idea of the concept underlying the pricing structure, without going into the details that distinguish each type of user.

Potable water charges distinguish between fixed and variable costs, which in turn distinguish between consumption in peak and off-peak periods. The monthly fixed charge, FC, is obtained from the expression

$$FC \cdot \sum_{t=1}^{35} \frac{\text{clients}_t - \text{clients}_0}{(1+r)^t} = \sum_{t=1}^{35} \frac{(\text{fixed costs})_t - (\text{fixed costs})_0}{(1+r)^t}.$$

In other words, the fixed charge distributes fixed costs that do not depend on the number of users, among all customers projected for the next 35 years (this projection is obtained from the pricing study). Expenses of this type mainly include administration and sales.

Variable charges distinguish between peak and off-peak periods. Consumption in the off-peak period only pays operating and maintenance costs (or variable expenses). The price per m^3 in the off-peak period, OC^n (the superscript *n* denotes off-peak), is obtained from the expression

$$OC^n \cdot \sum_{t=1}^{35} \frac{(\text{consumption})_t^n - (\text{consumption})_0^n}{(1+r)^t} = \sum_{t=1}^{35} \frac{(\text{variable expenses})_t^n - (\text{var iable expenses})_0^n}{(1+r)^t},$$

where $(\text{consumption})_t^n$ is monthly average consumption in the off-peak months of year *t,* and $(\text{variable expenses})_t^n$ represent average variable expenses in the off-peak months of that year.

Peak period consumption must cover capacity costs in addition to variable costs. The operating cost charge in the peak period, OC^p, is obtained, *mutatis mutandis,* from an expression analogous to that of OC^n. The capacity cost is assumed to be variable (in other words, for pricing purposes it is assumed that investment costs rise with the number of m^3 served). This gives the expression

$$CC \cdot (\#\,\text{peak months}) \cdot \sum_{t=1}^{35} \frac{(1-\tau)\left[(\text{consumption})_0^p - (\text{consumption})_0^p\right]}{(1+r)^t} = \Delta K - \sum_{t=1}^{35} \frac{\tau D_t}{(1+r)^t} - \frac{(\text{residual value})_{t=35}}{(1+r)^{35}},$$

where CC is the capacity charge per m^3, the superscript *p* denotes "peak" period, $(\text{consumption})_t^p$ is average monthly consumption during the peak period of year *t*, and ΔK is the updated investment of the expansion plan for the service.

CC, OC^n and OC^p are used to construct the price per m^3, distinguishing between peak and off-peak periods as follows. During the peak period, a customer's total consumption is divided between normal and overconsumption. Normal consumption consists of cubic meters that do not exceed the average amount consumed during the off-peak months. Overconsumption is the amount that exceeds the off-peak average. The price per normal m^3 is

$$OC^p + \frac{\#\,\text{peak months}}{12} \cdot CC.$$

The price per m^3 of overconsumption is

$$OC^p + CC.$$

Lastly, the price per m^3 in the off-peak period is

$$OC^n + \frac{\#\,\text{peak months}}{12} \cdot CC.$$

The formulas described above imply that all capacity is paid for exclusively by those who consume during the peak period, despite the charge of $(\#\,\text{peak months})/12 \cdot CC.$ which appears in the account during the off-peak period. To understand this point, note that the total annual account of a user that consumes q_n on average in each off-peak month, and q_p in each peak month (with $q_n < q_p$) is

$$\text{Total expenditure} = (12-m)(OC^n + \frac{m}{12}CC)q_n + m\left[(OC^p + \frac{m}{12}CC)q_n + (OC^p + CC)(q_p - q_n).\right]$$

$$= (OC^n + \frac{m}{12}CC)Q_n + \left[(OC^p + \frac{m}{12}CC)\frac{m}{12-m}Q_n + (OC^p + CC)(Q_p - \frac{m}{12-m}Q_n).\right]$$

where *m* is the number of peak months and *Q* is the total consumption during the period. Note that the increase in the account as result of consuming an additional m^3 in the off-peak period is

$$\frac{\partial \text{Total expenditure}}{\partial \mathrm{Q_n}} = (OC^n + \frac{m}{12}CC) + \left[(OC^p + \frac{m}{12}CC)\frac{m}{12-m} - (OC^p + CC)\frac{m}{12-m}\right] = OC^n.$$

When an additional m^3 is consumed in the off-peak period, the direct cost is $OC^n + m/12 \cdot CC$; nonetheless, this additional m^3 raises the limit from which overconsumption is charged during the peak period, thereby reducing the account by

$$\left(OC^p + m/12 \cdot CC\right) m/(12-m) - \left(OC^p + CC\right) m/(12-m) = \frac{m}{12} CC$$

during the peak period, by shifting the overconsumption limit. On the other hand, the direct cost of consuming an additional m^3 in the peak period is

$$\frac{\partial \text{Total expenditure}}{\partial \mathrm{Q}_{\mathrm{p}}} = OC^p + CC$$

In other words all capacity is charged to those who exceed their overconsumption limit during the peak period.

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