INCENTIVE REGULATION. PRICE CAP METHODOLOGY WITH EXOGENOUS EFFECTS

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INTRODUCTION

This paper analyses the problems of Price-Cap regulation faced with the risk associated with changes in variables that are uncontrollable or exogenous to electricity distribution companies, and proposes a solution to these problems without reducing the power of efficiency incentives.

The first section summarises the objectives of regulation and the different conflicts or trade-offs that can arise between them. The second section describes briefly the Price-Cap mechanism. The third and final section proposes a dynamic price-cap, which aims to separate the effect of the exogenous variables while preserving the incentives to reduce costs that are under the control of the companies.

OBJECTIVES OF REGULATION

The purpose of regulation is to ensure socially optimum results when competition cannot operate. "Regulation replaces the invisible hand of competition with direct intervention, with a visible hand [1]."

The paradigm or conceptual model that the regulators have used to fix their regulatory strategy is that of perfect competition, which in the absence of externalities and indirect taxes leads to a Pareto optimum. These are the rules that derive from this:

- Price = Marginal Cost
- Productive Efficiency = Incentives to reduce costs

The first rule turns out to be inapplicable to the case of the distribution of electricity, where demand growth is associated with decreasing marginal costs. If prices were applied that are equal to marginal costs, the companies would not cover their costs. So, in the absence of subsidies, this is a problem of the maximization of social welfare subject to the companies covering their economic costs. The optimum obtained is known as the second best. In the case of a single-product monopoly, the result of this process is fixing rates equal to the average cost, while in the case of multi-product monopolies, Ramsey prices apply.

Supposing that the company and the regulator hold identical information about the conditions of the industry, the regulator could simply calculate the optimum prices. However, in reality, the company holds better information than the regulator about:

- Costs and conditions of demand
- Activities that tend to reduce costs

In terms of principal-agent relationship theory, the former is a problem of hidden information, called “adverse selection”, and the latter is a problem of hidden action, called “moral hazard”. Given the lack of this information, known as asymmetric information, the regulator is unable to make decisions about which actions the company should take in order to operate efficiently and invest efficiently. Neither can it judge if the regulated company is operating and investing efficiently, just as the companies operating in free competition markets would do. The second objective is to transfer to the consumers the benefits obtained by the improvement in productivity, without discouraging the companies from a continuous search for optimality.

The Problem of Asymmetric Information

As Armstrong Cowan & Vickers [1] explain, faced with the existence of asymmetric information, in order to define an optimum regulatory strategy, there must be a trade-off between: (1) allocation efficiency in consumption, (2) productive efficiency, (3) minimization of the adverse distributive effects deriving from the above-normal profits the companies could obtain due to their advantages in terms of information.

Allocation Efficiency in Consumption. This aim is fully achieved when the rate is strictly adjusted to the economic cost of provision. Its extreme version would imply a regulation cost-plus scheme, in which there is no incentive to reduce costs.

Productive Efficiency. Its achievement implies that the company carries out an optimum level of efforts in cost reduction, as if it was operation in a competitive environment. The regulatory scheme that enables this to be fully achieved is the Price-Cap, in which unlinking the rates from the costs generates every incentive for the companies that want to improve their profits to reduce their costs optimally.

Adverse Distributive Effects. Even though the literature on regulation presents the situation where the companies do not obtain any above normal profit as an ideal situation, the company needs to have the possibility of retaining a proportion of the profits deriving from its cost reduction efforts in order to maintain the incentives.
This objective should be understood in the following way: without incentives there is no reduction in costs, and society obtains no benefit. The incentives are derived from the possibility of the companies’ improving their profits, and transferring a part of this improvement to the users. So that where incentives exist, the situation for the company and for the users is better than that in which the companies are not allowed to keep part of their improved profits, and so none are produced.

**PRINCIPLES OF REGULATION BY INCENTIVES**

The power of the incentives depends on two factors (Crew & Kleindorfer [3]):
- The degree of the unlinking between income and costs.
- The regulatory lag.

The greater the unlinking or the greater the lag, the greater is the power of the incentives. This leads us to look for, on the one hand, a total unlinking between prices and costs, as would happen in a market of free competition, and on the other, try to maintain this unlinking for as many years as possible. This will give us the most powerful incentives; the companies will quickly look for the maximum efficiency possible.

Nevertheless, total unlinking and long rate lags expose us to the risk that, for exogenous factors, costs become significantly separated from income, and produce either losses or profits unacceptable to the regulator. If the company suffers losses because its costs go up or because its income goes down, for exogenous reasons, it will be necessary to compensate it so that, operating efficiently, it can obtain the regulated rate of profitability. If, on the contrary, costs go down – as a result of deflation, or technological advances, or a fall in the exchange rate, for example – or income rises faster than costs, as a result of increased quantities sold, or greater concentration in the network, then profits will increase undeservedly, and the companies will be receiving higher profits than those regulated. In such cases it is desirable to pass on the extraordinary profits to the consumers, by reducing rates as soon as possible. In either of the two cases, it is necessary to make an extraordinary recalculation of rates before the end of the tariff period.

**Price – Cap**

The Price-Cap is the most commonly used mechanism for regulation by incentives since its first application by Littlechild in the UK in 1983.

An initial price is fixed that is kept constant for a period of n years, which in the case of electricity distribution is between 4 and 5 years. This price is normally indexed with:
- An index reflecting the evolution of the general price level or in some more developed cases the index is to a basket of inputs
- An “X” factor of efficiency that aims to transfer in real time part of the cost improvements achieved by the companies each year.

There are two approaches or methodologies for the calculation of the price-cap:
- **Static**: a photograph is taken of the company in the base year, and rates are calculated using the information on costs and demand in that year. The X factor arises from a negotiation between the regulator and the company.
- **Dynamic**: starting from the base year, a demand projection is made and its corresponding investment plan. Operating and maintenance costs are projected and rates are calculated for each year of the tariff period. These charges consider the improvements in efficiency deriving from the natural concentration that occurs in the networks as well as in the management of the company.

Fixing a rate charge vector based on demand in one historical year (static case) or in projected years (dynamic case) may lead to the situation where, given significant differences between the projected figures and those effectively made, the companies may not cover their costs, or may obtain profits way above their capital cost.

The main criticisms this mechanism presents derive from not having isolated all the variables that impact on the income of the companies and over which they have no control. This increases the regulatory risk, and may, in the long term, generate problems of under-investment.

**PROPOSAL OF A DYNAMIC PRICE CAP**

Here we will present a Price-Cap proposal for the rates for the use of capacity on the electricity distribution network. For the sake of simplicity, we exclude from this analysis the charges for other services provided by the distributor, such as Wholesale and Retail Commercial Services. We also exclude the components related to the cost of losses of energy in the network.

**Fundamentals**

The aim of this proposal is to reduce the risk inherent in formulating Price-Cap with high-powered incentives. The risk is reduced on the basis of adjusting the Price-Cap with X factors arising from an estimate of the impact produced by exogenous variables. Given the problems described before, and based on our experience in rates calculation based on Price-Cap, we have developed a Price-Cap mechanism that fully maintains the incentives to cut costs and enables the complete elimination of the risks associated with exogenous variables.

The tariff structure is designed using the share that each category has in the maximum demand of each tension level of the network, as the mechanism for distributing capacity costs.
Development

It is established that the total income for the sale of the rights to use network capacity (Value Added of Distribution, or VAD) will be equal to Capital Costs plus the Costs of Operation, Maintenance and Administration (CO&M) in the base year.

A structure of tariff charges is designed that enables the VAD to be recovered from the physical amounts sold in that year.

Equation (Error! Unknown switch argument.)

\[
\text{VAD} = \text{Costs} = \sum_{r} p_{r,0} Q_{r,0} = \sum_{r} w_{r,0} R_{r,0}
\]

where
- \( p_{r,0} \) = Prices of Rating Charges in the Base Year
- \( Q_{r,0} \) = Quantities Produced (sold) in the Base Year
- \( w_{r,0} \) = Prices of Resources in the Base Year
- \( R_{r,0} \) = Amount of Resources Used in the Base Year

The vector of tariff charges is fixed for an \( n \) number of years, in which there are particular exogenous variables, the evolution of which may make the income deviate significantly from the economic costs of provision, harming either the company or the clients.

These are the main variables that are not controllable by an electricity distribution company:
- Prices of the inputs
- Amounts produced\(^1\)
- Length of the lines\(^2\)

Currently, most of the known applications of individual price–cap have managed, imperfectly, to transfer variations in the prices of inputs to the users, but problems deriving from significant changes in the other exogenous variables, especially in the level and composition of demand, are still unsolved. So much so that most of the regulating by price–cap in Latin American countries allows extraordinary rate reviews when faced with unexpected variations in demand. With the objective of simultaneously obtaining high power incentives and avoiding the risk of exogenous variations, a formula has been designed for automatic price-cap adjustment that compensates for the impact of changes in such variables.

Rewriting equation (1) in terms of index numbers:

\[
\text{Equation (Error! Unknown switch argument.)}
\]

\[P \times Q = C\]

being
- \( P \) = Index of Product Prices
- \( Q \) = Index of Amounts of Products
- \( C \) = Cost of Network Capacity

Resolving \( P \):

\[
\text{Equation (Error! Unknown switch argument.)}
\]

\[P = \frac{C}{Q}\]

Taking logarithms
\[\ln P = \ln C - \ln Q\]

Differentiating in terms of time:

\[
\text{Equation (Error! Unknown switch argument.)}
\]

\[
\frac{\partial P}{\partial t} = \left( \frac{\partial C}{\partial t} - \frac{\partial Q}{\partial t} \right)
\]

\[P = \frac{C}{Q}\]

Bauer [2], Lowry [9] and Rodríguez [10], disaggregated the Total Factor Productivity in its differences sources. In the same way, we decomposed the price variations according to the nature of the variables producing them, in those controllable and not controllable by the company. The former we call endogenous and the latter are defined as exogenous.

- Exogenous Variables
  - Observable During the Tariff Period
    - Evolution of Prices of Inputs
    - Evolution of Level and Composition of Demand
      - Maximum Capacity Demanded (Power)
      - Number of Clients
      - Area Covered
      - Spread of Consumers
  - Not Observable During the Tariff Period
    - Technological Change
- Endogenous Variables
  - Improvements in the usage of inputs

Most formulas for indexing the price–cap use \( X \) or \( K \) factors that, in the best case, arise from a price–cap calculation based on a dynamic approach. As we have said before, these schemes have not solved the problems caused by unexpected changes in demand or in the level of investments. The scheme proposed here is for the periodic calculation of the \( X \) factor that enables the capture exclusively of changes in the exogenous variables observable during the Tariff Period.

Decomposition of the Evolution of the VAD. This begins with the supposition that the VAD is equivalent to the real cost of provision calculated in the base year.

In an electricity distribution company, its most important

\(^1\) Given that the energy cannot be stored, the amounts produced coincide with those sold. Energy losses in the network are considered as internal to the companies since they are inherent to energy distribution, so production is considered as the energy effectively delivered to the clients. We stress that the distributors sell a set of differentiated products whose costs are different.

\(^2\) Most electricity distribution companies have zone exclusivity and have the obligation to provide energy to new customers situated at a distance from the existing lines lower than a limit pre-established in the concession contracts.

\(^3\) There are cases where negative \( X \) factors have been fixed that increase the price–cap, and these are commonly known as \( k \) factors.

\[
\begin{array}{|c|c|c|c|c|}
\hline
\text{Variable} & \text{Description} & \text{Not Observable During the Tariff Period} & \text{Observable During the Tariff Period} & \text{Endogenous Variables} \\
\hline
\text{Costs} & \text{CO&M} & \text{Technology Change} & \text{Evolution of Prices of Inputs} & \text{Improvements in the usage of inputs} \\
\hline
\text{Capacity Network} & \text{Maximum Capacity Demanded (Power)} & & & \\
\hline
\text{Maximum Capacity Demand} & \text{Number of Clients} & & & \\
\hline
\text{Area Covered} & \text{Spread of Consumers} & & & \\
\hline
\end{array}
\]
resource is its capital. There are two reasons for this:

- The cost of capital is the largest part of the VAD
- Capital is the cost driver of the costs of operating and maintaining the network

Taking into consideration this characteristic of the function of cost, this can be expressed as a function of the capital base ($K$), of the prices of the inputs ($W$) and of time:

$$C = f(K, W, t)$$

Establishing a Cobb-Douglas type function, transforming into logarithms and differentiating with respect to (t):

$$\ln C = \ln f(K, W, t)$$

$$\frac{\partial C}{\partial t} = \frac{\partial f}{\partial K} \frac{\partial K}{\partial t} + \frac{\partial f}{\partial W} \frac{\partial W}{\partial t} + \frac{\partial f}{\partial t}$$

The growth rate of optimal cost can be seen as the sum of two terms. The first is the sum of the products of the growth rates of the explanatory variables and their corresponding cost elasticities. The second term, $\hat{A}$ is the percentage variation of cost over time, which represents the technological change and any improvements in efficiency thanks to better business management.

Shephard’s lemma [11,12] says that the derivative of optimum cost with respect to the price of an input is the optimal input quantity. Consequently, optimal cost elasticity with respect to the price of each input $j$, is the optimal share of this input in the optimal cost ($s$). In the same way we can replace the cost elasticities with respect to the components of the capital base by their shares in the total cost. Error! Unknown switch argument. can be expressed as:

$$\hat{C} = \sum_i s_{ki} \times \hat{K}_i + \sum_j s_{wj} \times \hat{W}_j + \hat{A}$$

replacing

$$\hat{W} = \sum_j s_{wj} \times \hat{W}_j$$

and

$$\hat{K} = \sum_i s_{ki} \times \hat{K}_i$$

Finally, the cost variation will remain expressed as follows:

$$C = K + W + A$$

As Rodriguez [10] stand, the second term of the right side of the equation, $\hat{W}$, is the weighted average of the rates of variation of the input prices, that constitutes a Divisia [7] index of variation of the input prices.

The capital base $K$ was classified as an observable exogenous variable, given that, since there is an obligation to provide the service, common to concessions for electricity distribution, this is determined by the evolution of demand, which is a set of uncontrollable variables.

We propose the following Cobb Douglas function for the capital $K$:

$$C = L^\alpha \times Clie^\beta \times Q^\chi$$

where:

- $L$ = Length of Network
- $\alpha$ = Cost Elasticity with respect to length of Network
- $Clie$ = Number of Clients
- $\beta$ = Cost Elasticity with respect to number of Clients
- $\chi$ = Cost Elasticity with respect to amount of Energy sold

Transforming into logarithms and differentiating with respect to (t):

$$\ln C = \ln L^\alpha \times Clie^\beta \times Q^\chi$$

$${\partial C \over \partial t} = \alpha \times {\partial L \over \partial t} + \beta \times {\partial Clie \over \partial t} + \chi \times {\partial Q \over \partial t}$$

and replacing in Error! Unknown switch argument. will give:

$$\dot{C} = \alpha \times \dot{L} + \beta \times \dot{Clie} + \chi \times \dot{Q} + \hat{W} + \hat{A}$$

and replacing the cost variation in the price variation formula

$$P = \alpha \times L + \beta \times Clie + \chi \times Q + W + A - Q$$

Ordering terms will give:

$$\dot{P} = \dot{W} + \left[ \alpha \times \dot{L} + \beta \times \hat{Clie} + (\chi - 1) \times \dot{Q} \right] + \hat{A}$$

where the Exogenous Efficiency Factor $X$ is defined as:

$$X = (1 - \chi) \times Q - \alpha \times L - \beta \times Clie$$

With the variation of $P$ finally remaining, explained by three factors:

$$\dot{P} = W - X + \hat{A}$$

The first term on the right side is, as mentioned above, a Divisia index of input prices, which is exogenous. The second is an efficiency factor measuring the economies of concentration in the network that may have positive, negative or zero values. In general, its value will be positive, reflecting the cost reduction produced by the demand concentration due basically to vertical growth. Nonetheless, in crisis situations or economic recession, its value may be negative, reflecting an increase in average costs. Finally, the third factor measures the effect produced by technological change and the improvements achieved by
better business management. This factor is considered to be endogenous in origin since, even in the case of technological change, for this to have an impact on the costs of the company, its implementation is dependent on the company’s decision. In general, the incorporation of new technologies requires investment, training of human resources, and frequently implies research and development efforts that are not without risk. For these reasons we consider that this component is endogenous. The Price-Cap adjustment will then be resolved applying the traditional formula:

\[ P_{\text{Price-Cap}} = W - X \]

where the X factor is calculated on the basis of **endogenous variable**.

We suggest that the application of **endogenous variable** should be annual, as long as the resulting variations are not greater than the maximum percentages permitted for such adjustments, that we estimate in a range of from 1 to 5%.

**EXAMPLE OF PRACTICAL IMPLEMENTATION**

Based on statistical information from 81 U.S. electricity distribution companies from the year 2000, published by the Federal Energy Regulatory Commission (FERC), an estimate was made by ordinary least squares of the capital base function with the variables in logarithms. The results of the regression were as follows:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient Name</th>
<th>Coefficient</th>
<th>Error</th>
<th>t-statistic</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ln(LMT)</td>
<td>( \alpha )</td>
<td>1.26387</td>
<td>.056744</td>
<td>2.26266</td>
<td>[0.08]</td>
</tr>
<tr>
<td>Ln(CLIE)</td>
<td>( \beta )</td>
<td>1.04504</td>
<td>.158783</td>
<td>5.00344</td>
<td>[0.00]</td>
</tr>
<tr>
<td>Ln(E)</td>
<td>( \chi )</td>
<td>.350475</td>
<td>.084039</td>
<td>4.17042</td>
<td>[0.00]</td>
</tr>
</tbody>
</table>

The statistics associated with this equation enable us to infer that the model presented significantly explains the behaviour of \( \ln(K) \), reflecting a direct relation with all the variables.

**Normal Growth Case**

Supposing that the exogenous variables show the following values:

\[ \hat{Q} = 5\%; \hat{L} = 2\%; \hat{CLIE} = 3\%; \hat{W} = 4\% \]

The calculation of X will give the following value:

\[ X = (1 - \chi) \times \hat{Q} - \alpha \times \hat{L} - \beta \times \hat{CLIE} \]

\[ X = (1 - 0.35) \times 5\% - 1.28 \times 2\% - 0.594 \times 3\% \]

\[ X = 1.21\% \]

Replacing X in the Equation (17):

\[ P_{\text{Price-Cap}} = W - X \]

\[ P_{\text{Price-Cap}} = 4\% - 1.21\% = 2.79\% \]

**Economic Recession Case**

Supposing that the exogenous variables show the following values:

\[ \hat{Q} = 4\%; \hat{L} = 1\%; \hat{CLIE} = 2\%; \hat{W} = 0\% \]

In **endogenous variable**), the capital elasticities in the face of negative variations in the exogenous variables are zero since it is not possible, in the short and medium term, to remove the installations or stop operating and maintaining them. Bearing this in mind, the calculation of X will give the following value:

\[ X = (1 - \chi) \times \hat{Q} - \alpha \times \hat{L} - \beta \times \hat{CLIE} \]

\[ X = (1 - 0) \times (-4\%) - 1.28 \times 1\% - 0.594 \times 2\% \]

\[ X = -5.32\% \]

Replacing X in the Equation (17):

\[ P_{\text{Price-Cap}} = W - X \]

\[ P_{\text{Price-Cap}} = 0\% - (-5.32\%) = 5.32\% \]

As can be seen, despite the input prices remaining constant as a result of the recession, the Price-Cap must be adjusted upwards, to reflect the fall in sales that produces increases in the average cost. In this way the adjustments in the VAD are produced automatically, maintaining the profitability of
the regulated company in the face of changes in the exogenous variables affecting it.

REFERENCES


