Institutions, Regulatory Policy Choice and Efficiency in the Telecommunications Industry*

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Abstract

During the past decades, competition and regulation were introduced in industries formerly characterized by vertically-integrated state-owned monopolies. As noted by some authors, the specific policy design and the outcome of the reforms are affected by the institutional environment and governance mechanisms prevailing in a given country. This paper proposes a method to evaluate efficiency and performance of the fixed-telephony sector in a selection of developing countries. In particular, we study the impact of the type of regulatory policy on the industry's production frontier, taking into account that the choice of policy is influenced by industry characteristics, efficiency and the county-specific institutional environment. We find that our method improves the fit of the stochastic production function with respect to a model where the choice of policy is taken to be exogenous. Additionally, we find that the probability that we observe a high-powered policy such as price-cap increases with the industry's efficiency. We also estimate the impact of institutional and regulatory governance variables.

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1 Introduction

The massive industrial reform programs introduced in many countries since the 1980's brought about a drastic change in the role of the state in the economy. Restructuring and competition were introduced in markets formerly characterized by vertically-integrated state-owned monopolies. However, the scope of the reforms was generally limited in the infrastucture industries, due to the natural monopoly aspect of some segments. Most countries still maintain some control over these industries through regulatory agencies. The role of the state becomes one of designing a proper regulatory structure, in order to ensure efficiency and a fair share of rents among economic agents.

The implementation of the reforms has not been a trivial task. Most countries – especially the developing ones – went through this process constrained by their own lack of expertise on the matter and poor awareness about the proper functioning of the new paradigm. Particularly, complex industries such as energy and telecommunications have often been object of a *trial-and-error* procedure, as the involved parties tried to find their way through the reform process.

As argued by Levy and Spiller (1994) and Noll (2000), different institutional environment and governance mechanisms yield reforms that differ in form and scope. While many countries have adopted widespread privatization programs, others have opted for punctual changes in the industries' ownership structure. In some countries, industry restructuring was implemented; others have chosen to keep their industries vertically-integrated. Furthermore, many countries implemented piecewise/sequential reforms, while others opted for once-and-for-all programs with the implementation of simultaneous reforms.

Following the above authors, we separate a country's regulatory structure into two components: regulatory governance and incentive policy. Regulatory governance comprises the mechanisms used by society to constrain regulatory discretion and resolve conflicts that arise from the interaction among agents. The incentive policy concerns the rules which the utility is directly subject to, such as pricing, entry and interconnection policies, and rules regarding direct or cross-subsidies. We take the view that the regulator's essential activity consists in the design of the incentive policy, while the governance structure is defined by higher levels of government subject to the country's institutional background.[1]

In this context, it is clear that the behaviour of regulators and regulated utilities, and therefore their performance, is affected by the overall institu-

[1] Noll (2000) calls these three dimensions the forest (institutional environment), the trees (regulatory governance) and the leaves (regulatory policy) of the regulatory structure.

tional environment and the regulatory governance structure in the country. For example, we would expect that, in countries with unstable institutions, regulators would opt for an incentive policy that protects the utility's payoff rather than exposing it to fluctuations of the economic or political conditions; in other words, the more unstable the country, the more the regulatory authority would be willing to choose a low-powered regime such as rate-of-return. Similarly, the less transparent the regulatory governance rules are, the higher the uncertainty regarding the actual implementation of the incentive policy. In such a situation, the regulator might also be willing to protect the utility's payoff through a regime that can diminish the uncertainty over returns, one closer to rate-of-return.

The aim of this paper is to elaborate a method to evaluate the performance and the efficiency of the telecommunications industry in a selection of developing countries, taking into account the policy choices by the regulatory agencies, the regulatory governance and the institutional environment of the country. In order to do that, we borrow from the literature on stochastic frontier analysis and the new empirical studies on the impact of incentive regulation. We particularly build upon the work of Gagnepain and Ivaldi (2002), which develops a stochastic frontier method for identifying inefficiency in regulated industries. We then incorporate the issues raised in Levy and Spiller (1994) on the determinants of the performance of privatized utilities in different institutional, political and social environments.

There has been extensive empirical work on the impacts of the overall reforms on the performance of the regulated sectors; however, the same is not true for the impact of the specific regulatory policies on the utility's performance. In fact, the studies on the role and the impacts of regulators have not given straightforward answers. Most of them neglect the fact that the regulatory process is endogenous and that regulators are subject to political forces and institutional constraints that may prevent them from doing their job properly. By recognizing that the regulator's policy choices are endogenous, that is, a function of the above mentioned factors, we are able to get a better measure of the impact of the regulatory policies.

Although the analysis below focuses on the fixed-line telecommunications market, most of our theoretical arguments and the econometric model apply to other infrastructure industries under the supervision of a regulatory agency, such as electricity, water or transportation. Our choice of market was based on the availability of comprehensive data on telecommunications regulatory governance and policy in several developing countries. These data were gathered by the World Bank and comprise answers from the regulatory agencies to a questionnaire proposed in 2001 on the governance and incentive structure in their respective countries. The questions included issues such as the type of price regulation used on the different telecommunications market segments, the agency's sources of financing, methods of appointment of the regulatory body, the licensing policies and the detail about the regulator's decision-making process. Besides, the International Telecommunications Union (ITU) provides an extensive database on the industry's performance and structure, with information on the density of the network, production and investment related variables as well as several quality measures for both mobile and fixed lines. The institutional data were gathered from a variety of sources.

This paper is organized as follows. The next section presents the theoretical model, describing the agents and their respective behaviour. Then, in section 3, we outline the econometric methodology. In section 4, we describe the datasets used in the analysis and present some descriptive statistics. Next, section 5 introduces the results. Section 6 concludes.

2 Theoretical Background

We have two agents in the model: the regulatory agency and the utility. We begin this section by describing the production technology. We then procceed to define the set of policies available to the regulator and to analyse the problems of the regulator and of the utility.

2.1 The Technology

The utility chooses the combination of inputs and cost reducing effort that maximizes its payoff subject to the regulator's policies and the institutional endowments. Notably, the theory of regulation establishes that under asymmetric information, the level of cost-reducing effort is affected by the choice of the regulatory regime. In particular, a regulatory policy is called "high-powered" if it induces a high level of cost-reducing effort and "low-powered" otherwise.

We represent the utility's technology as follows. The production process is subject to some degree of technical inefficiency which leads to underproduction relative to the maximum potential amount given the quantity of inputs used. This technical inefficiency is indicated by a parameter θ, which is exogenous, i.e., it is not under the control of the utility or the regulator. However, the utility can reduce the distortion between the potential and the actual output levels by exerting an amount of effort e. The inputs necessary for production are capital (K) and labour (L). Letting Q be the output, the production function can be expressed as:

$$Q = A \exp(-(\theta - e))K^{\beta_K} L^{\beta_L},$$

where the term $\exp(-(\theta - e))$ measures the output distortion and A is a technological parameter. As indicated in the function, the higher the level of effort, the lower the global inefficiency $\theta - e$. Note that when the firm makes a high enough effort, say $e = \theta$, then production reaches its feasible maximum.

In practice, the level of effort elicited by any incentive structure depends not only on the incentives provided by the regulatory policy, but also on what the utility knows about the functioning of the governance and institutional settings of the country. In this context, we would expect that, *ceteris paribus*, the effort level provided by firms under the same regulatory regime would not be the same in countries with different regulatory governance structure and institutional endowments. For example, we expect that a high-powered regulatory regime such as price cap will induce relatively less effort if the country is politically unstable or the regulatory governance structure is not clear, so that the firm expects the government to have scope to behave opportunistically.

2.2 The Regulatory Policy

We assume the regulated utility derives its payoff from its operational revenues and a transfer received from the state, net of costs (including the cost of effort). In particular, the utility's payoff may be written as:

$$U = t + R(Q) - C(Q, \theta, e) - \psi(e), \tag{1}$$

where $R(\cdot)$ is the revenue function, t is the transfer made by the public sector to the utility, $C(\cdot)$ is the production cost and $\psi(\cdot)$ is the utility's monetary measure of exerting a cost reducing effort.

As standard, we assume that $\psi'(\cdot)$ and $\psi''(\cdot)$ are strictly positive, and that $\psi(0) = 0$. As we will see below, Q and t in the above problem are functions of the policy chosen by the regulator.We assume that the regulator chooses the incentive policy after observing the governance structure and institutional environment. Therefore, we modify the timing of Levy and Spiller (1994), where regulatory policy and the governance are chosen simultaneously by the policy-makers as a function of the institutional environment.

We adopt the "public interest" approach that assumes that the regulator maximizes society's welfare. We further assume that it will be accountable for its policies the better its respective regulatory governance is settled, that is, the appeal rights are well established and society is able to represent its interest in a public forum. In this context, the regulator's policies are its best reponse, regarding society's interest, to the regulatory governance structure, informational asymmetry and institutional endowments[2].

Following Laffont and Tirole (1993), we define $S(\cdot)$ as consumers' gross surplus and λ as the shadow cost of public funds. Let us state the social welfare function as:

$$W = S(Q) + \lambda R(Q) - (1+\lambda)[C(Q,\theta,e) + \psi(e)] - \lambda U. \qquad (2)$$

A regulatory policy can be taken to be a triple (Q, e, t), in which the regulator determines the output (or equivalently the price), the firm's cost-reducing effort and the transfer. Theoretically, as shown in Laffont and Tirole (1993), the optimal policy consists in the regulator offering a menu of such triples, one for each "type" θ of firm. The revelation principle guarantees that the firm will pick the item in the menu which corresponds to its type. However, in practice, regulators usually choose between two polar regimes: fixed-price (high-powered) or rate-of-return (low-powered).[3]

Under a fixed-price regime, the utility receives a fixed transfer, $t = t^{fp}$. In particular, this transfer does not depend on the cost or revenue levels. However, we assume that in countries with weak institutional settings, there is a probability that the firm will be partly expropriated if it makes positive profit, or that it will be able to capture the regulator and be partly reimbursed if it makes a loss. We assume that this probability is given by a variable μ, which itself is a function of the regulatory governance and institutional endowments, $\mu = \mu(INST)$. A stronger institutional background is reflected by a value of μ close to 1, while weak institutions are reflected by low values of μ. Formally, the assumption is that the expected transfer to the utility under a fixed-price policy is $t = t^{fp} - (1-\mu)[R(Q) - C(Q,\theta,e)]$. Substituting in (1), its payoff is given by:

$$U^{fp} = t^{fp} + \mu[R(Q) - C(Q,\theta,e)] - \psi(e).$$

Under a rate-of-return policy, the regulator reimburses the firm for any differences between costs and commercial revenues, possibly giving it an additional amount t^{rr}. The total transfer is thus $t = t^{rr} + [C(Q,\theta,e) - R(Q)]$. Contrary to the previous case, we assume that the expected transfer under

[2] A summary discussion on the challenges the "public interest" approach has been object of can be found on Laffont (part II, 2000).

[3] To be sure, regulatory policies in some countries consist in an intermediary case, such as profit-sharing contracts. For simplicity, we will only consider the two polar cases in our analysis.

rate-of-return policy is not affected by institutional factors. The key assumption that we wish to capture in the model is that the utility's return under fixed-price is more sensitive to institutional factors than under rate-of-return. In this case, the utility's payoff will be:

$$U^{rr} = t^{rr} - \psi(e).$$

2.3 The utility's problem

Letting $\rho \in \{0, 1\}$, where $\rho = 1$ means a fixed-price policy and $\rho = 0$ is rate-of-return, the firm's payoff can be stated as $U = \rho U^{fp} + (1 - \rho)U^{rr}$. The utility's problem can then be written as:

$$Max_e \ \rho t^{fp} + (1 - \rho)t^{rr} + \rho\mu[R(Q) - C(Q, \theta, e)] - \psi(e).$$

It is easy to see that the effort level that solves this problem is a function of ρ, characterized by:

$$\psi'(e^*) = -\mu \frac{\partial C(Q, \theta, e^*)}{\partial e}, \text{ if } \rho = 1 \tag{3}$$

$$e^* = 0, \text{ if } \rho = 0.$$

Following Gagnepain and Ivaldi (2002), let us assume that the effort function is given by $\psi(e) = \exp(\alpha e) - 1$. Furthermore, assume that the cost function is given by:

$$C(Q, \theta, e) = (\theta - e)Q^{\beta_Q}.$$

This cost function is similar to the one used in Laffont and Tirole (1993, ch. 2), except for the parameter $\beta_Q \equiv 1/(\beta_K + \beta_L)$ that allows for non-constant returns to scale.[4] Applying the above functional forms for the effort and cost functions to the first-order condition given in (3), we obtain a closed form solution for the optimal effort level under a fixed-price regime:

$$e^* = \frac{1}{\alpha} \left[\beta_Q \ln Q - \ln \alpha + \ln \mu \right].$$

[4] It should be noted that this is *not* the Cobb-Douglas dual cost function, which is given by $C = B \exp[(\theta - e)/\beta_Q] w_L^{\beta_L/\beta_Q} w_K^{\beta_K/\beta_Q} Q^{\beta_Q}$, where B is a constant and w_L and w_K are the input prices. We do not use the Cobb-Douglas dual cost function in our analysis due to the lack of data on input prices.

Substituting the values of the effort variable into the production function, we have that production, in logarithmic form, under a rate-of-return policy and under a fixed-price policy are respectively given by:

$$\ln Q = \beta_0 + \beta_K \ln K + \beta_L \ln L - \theta. \tag{4}$$

$$\ln Q = \widetilde{\beta}_0 + \gamma\left[\beta_K \ln K + \beta_L \ln L - \theta\right] + (\gamma/\alpha)\ln \mu. \tag{5}$$

In the above expressions, we have $\beta_0 \equiv \ln A$, $\widetilde{\beta}_0 \equiv \gamma[\ln A - (1/\alpha)\ln \alpha]$ and $\gamma \equiv \alpha/(\alpha - \beta_Q)$. Notably, the parameter γ measures the impact of fixed-price regulation on the production frontier and on the marginal productivity of inputs. Its sign is not *a priori* clear, as it depends on the relative values of the effort and the returns-to-scale parameters. If, as theory suggests, fixed-price regulation has the effect of increasing productive efficiency and reducing the output distortion with respect to rate-of-return, we would expect $\gamma > 1$. This effect, however, may be counterbalanced by the last term in (5), which reflects the fact that the firm may be more easily expropriated under a fixed-price policy.[5]

2.4 The regulator's problem

By substituting the appropriate values for e and U into the welfare function (2), we get the value of the social welfare under the two regimes, $W^{rr}(Q, \theta; INST)$ and $W^{fp}(Q, \theta; INST)$. The value of the welfare function depends on the regulatory governance and institutional environment of the country, summarized by $INST$, through the parameter μ. The regulatory agency chooses its incentive policy taking into account the reaction of the regulated utility. Since we are assuming that the choice of regulatory policy is binary, the maximization of the social welfare function can be stated as:

$$\underset{\rho \in \{0,1\}}{Max}\ E_\theta\left[\rho W^{fp}(Q, \theta; INST) + (1-\rho) W^{rr}(Q, \theta; INST)\right].$$

The decision rule is then:

$$\rho = 1 \text{ iff } \Delta W \equiv E_\theta\left[W^{fp}(Q, \theta; INST) - W^{rr}(Q, \theta; INST)\right] \geq 0. \tag{6}$$

3 Econometric Methodology

In analogy to the methodology of Gagnepain and Ivaldi (2002), the production function to be used in the estimation is obtained by putting together equations (4) and (5) as follows:

[5] Note that this last term is negative whenever γ is positive, since μ is between 0 and 1.

$$\begin{aligned}\ln Q &= \rho[\widetilde{\beta}_0 + \gamma(\beta_K \ln K + \beta_L \ln L - \theta) + (\gamma/\alpha)\ln\mu] + \\ &\quad (1-\rho)\left[\beta_0 + \beta_K \ln K + \beta_L \ln L - \theta\right].\end{aligned}$$

We are, therefore, using a primal approach, that is, we use the production function instead of the dual cost function in the estimation process. The main reason for doing this is that we do not have data on input prices, which is necessary to estimate a cost function. However, as discussed in Coelli et al. (2003), there are several advantages of using a primal instead of a dual approach in regulated industries, especially for cross-country analyses as the present one; for example, the dual approach requires the assumption of cost minimizing behaviour, which may be a very strong hypothesis in the context of regulated industries.

The regulator's choice equation to be estimated is given by expression (6). Assuming that the regulator is subject to errors in evaluating social welfare and that there are factors unobserved by the econometrician that affect the productive efficiency, we introduce random error terms, u_1 and u_2, in the two estimating equations. Specifically, since the variable μ is not observed, we include it in the error term of the production function. Therefore, the econometric model can be summarized by the following pair of equations:

$$\begin{aligned}\Delta W_{it} &= w(Q_{it}, \theta_{it}, INST_{it}) + u_{1it} \\ \ln Q_{it} &= q(K_{it}, L_{it}, \theta_i, \rho_{it}) + u_{2it},\end{aligned} \tag{7}$$

Of course, we do not observe the latent variable ΔW_{it}, but only $\rho_{it} = 1$ if $\Delta W_{it} \geq 0$ or $\rho_{it} = 0$ if $\Delta W_{it} < 0$. Thus, the first equation has a discrete dependent variable, where the regulator's policy choice is "explained" by a non-linear probability model. In particular, we will adopt a probit model for the policy choice equation. The vector $INST$ includes factors such as political stability, corruption control and independency of the regulator. The function $w(.)$ also contains variables reflecting industry structure, such as total fixed-telephony subscribers and the size of the wainting list for a fixed line.

Even though our methodology calls for observing the type of policy in country i at every period t, we only have data for the regulatory regime in 2001. To overcome this problem, we will estimate the model under two different assumptions. First, we may that this regime is valid for all time periods for which we have production data, that is, from 1994 to 2004. Alternatively, we may assume that the regulator only chooses a regime at one point in time and that it does not change for the remaining periods; in particular we will assume that the choice of policy is made on the year in which the most relevant sectoral reform occurred.

This is a mixed structure model as described in Maddala (1983). The estimation method should take into account that ρ_{it} will potentially be endogenous in the production equation, since the unobserved inefficiency parameter θ_i from the production frontier also enters the policy choice equation. Moreover, the choice of policy is affected by the same institutional factors that determine the unobserved variable μ implicitly included in the error term u_{2it}.

The suitable likelihood function for this simultaneous equations model will be derived from the joint distribution of (ρ_{it}, q_{it}) given θ_i, which will be denoted as $f(\rho_{it}, q_{it}|\theta_{it})$. Let the distributional assumption for the error structure be:

$$\left(\begin{array}{c} u_1 \\ u_2 \end{array} \right) \sim N\left(0, \Sigma\right), \text{ where } \Sigma = \left(\begin{array}{cc} 1 & \sigma_{12} \\ \sigma_{12} & \sigma_2^2 \end{array} \right).$$

Since $\rho_{it} = 1$ if and only if $w(Q_{it}, \theta_{it}, INS_{it}) \geq -u_{1it}$, the resulting joint density can be written as:

$$\begin{aligned} f(\rho_{it}, q_{it}|\theta_{it}) &= \rho_{it} \int_{-\infty}^{w(Q_{it},\theta_{it},INS_{it})} \phi(u, \ln Q_{it} - q(K_{it}, L_{it}, \theta_i, \rho_{it}))du \\ &\quad +(1-\rho_{it}) \int_{w(Q_{it},\theta_{it},INS_{it})}^{\infty} \phi(u, \ln Q_{it} - q(K_{it}, L_{it}, \theta_i, \rho_{it}))du. \end{aligned}$$

In the above expression, ϕ is the bivariate normal density function. Since the variable θ is not observed, we have to compute the unconditional joint distribution $f(\rho_{it}, q_{it})$. Following the literature on stochastic frontier, we assume that θ has a half-normal distribution with variance σ_θ^2. For simplicity, we assume here that this parameter is independent of the regulatory choice, input quantities and institutional factors. The likelihood for the observation corresponding to country i in year t is then:

$$f(\rho_{it}, q_{it}) = \int_0^{\infty} f(\rho_{it}, q_{it}|\theta) \sqrt{\frac{2}{\pi}} \frac{1}{\sigma_\theta} \exp\left\{ -\frac{\theta^2}{2\sigma_\theta^2} \right\} d\theta. \tag{8}$$

Assuming that observations are independent, the log-likelihood function to be maximized is obtained by summing up the logarithms of the individual unconditional density functions given in (8).

4 Data

In this section, we describe the dataset and present some descriptive statistics about the countries' institutional background and regulatory governance structure.

We use data on selected developing countries' telecommunication industry obtained from the International Telecommunications Union (ITU). This includes data on annual investment for telephone service and telecommunications, cable modem Internet and television subscribers, cellular mobile telephone subscribers, gross fixed capital formation, main telephone lines in operation, mobile communications staff and total fulltime telecommunications staff, number of national long distance telephone in calls and minutes and total national telephone traffic, total telephone subscribers, telephone faults per 100 main lines, waiting list for main lines, among others. These variables correspond to the ones needed for our production frontier estimation.

The regulatory data is obtained from the World Bank's Telecommunications Regulation Database. It includes data on 46 developing countries and presents answers from each country's regulatory body or Ministry to a survey on the characteristics of their regulatory structure, which includes the age of the regulatory agency, year of the most relevant telecommunications and privatization laws, type of regulatory regime for fixed and mobile telephony, whether it is a multi-sector agency, financing sources, among others. The data and the survey methodology are extensively discussed in Wallsten et al. (2004).

As for the institutional variables, we use the Aggregate Governance Indicators from Kaufmann, Kraay and Mastruzzi (2005), which have annual data from 1996 to 2004 on 6 governance indicators: (i) voice and accountability; (ii) political stability; (iii) government effectiveness; (iv) regulatory quality; (v) rule of law; and (vi) control of corruption.

Table I in the appendix shows the regulatory regimes for fixed telephony. We have assigned to each country a polar regulatory regime (price-cap or rate-of-return) as an approximation to the *de facto* regime. Table I shows that 28 out of 46 countries have adopted price-cap regime, while 10 declared rate-of-return; moreover, there are 5 countries that have declared having no regulatory regime and 3 that did not answer the question.

Table II presents the timing of relevant privatization or telecommunications reform. We note that important reforms concentrated on the mid 90's, with 45% of the countries issuing laws between 1994 and 1997.

Table III presents statistics on the telecommunications network size before and after the relevant reforms by type of regulatory regime. Notably, the countries that have adopted price-cap perform well on mobile subscriptions and badly on fixed lines, while the countries that have adopted rate-of-return perform better on total subscriptions of fixed line and mobile. The countries that have declared no regulation or not declared at all are doing very well on total subscriptions of fixed line and mobile.

Table IV shows statistics on institutional indicators by regulatory regime. Clearly, all the statistics confirm the prior that countries with bad governance indicators are going to choose a more flexible regime to compensate players from the high risk of investing in the country. Notably, the countries that have declared having no regulatory regime (3rd column) share the same if not worse institutional characteristics of countries that have chosen rate of return. Apparently, the regulator finds either useless to declare anything or finds it inappropriate to try to compromise to any regime.

5 Estimation Results

We begin this section by providing results for each of equation of our model estimated separately, using traditional single-equation methods. This procedure ignores the possible endogeneity of ρ in the production frontier equation and does not control for the effect of the inefficiency parameter θ in the regulatory policy choice equation.[6] We will later compare the results of this preliminary method with the ones from the maximum-likelihood method proposed in section 3.

Table 1 shows single-equation probit estimates of the choice of regulatory regime for different configurations of explanatory variables. We find that a higher network density, measured by the total number of fixed telephone subscribers per 100 inhabitants, the higher the probability of choosing rate of return regulation.

Regarding the institutional variables, political stability increases the likelihood that the regulator will choose a high-powered scheme such as price-cap, as expected.

[6] We are not aware of previous studies of production frontier in regulated industries in which the endogeneity of the regulatory policy is taken into account.

Dependent variable: D=1 if price cap; D=0 otherwise	(1)	(2)	(3)	(4)	(5)
Political stability	1.201 (2.41)**	1.379 (2.58)***	0.762 (1.78)*	1.342 (2.38)**	3.008 (1.90)*
Corruption control	-0.770 (1.32)	-1.170 (1.77)*	-1.251 (1.83)*	-1.442 (1.99)**	-3.359 (2.13)**
Possibility to appeal decisions					0.777 (1.75)*
Regulator fixed term	1.088 (2.35)**	1.172 (2.43)**	1.139 (2.35)**	1.215 (2.30)**	
Tel. subscribers/100 inhab.	-0.649 (1.96)**	-1.237 (2.39)**		-1.198 (2.22)**	-2.621 (1.87)*
GDP per capita		0.803 (1.56)	-0.103 (0.34)	0.822 (1.56)	2.238 (1.71)*
Waiting list for telephone line			-0.217 (1.60)	-0.157 (1.10)	-0.560 (1.83)*
Constant	1.332 (1.32)	-3.237 (1.05)	2.659 (1.02)	-1.714 (0.49)	-7.521 (1.05)
Observations	45	45	44	44	29

Absolute value of z statistics in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 1: Regulatory Policy choice

It is interesting to note that the other variable supposed to reflect institutional quality, i.e., corruption control, has a negative influence on the probability of price-cap. Indeed, Laffont (1995) argues that the effect of corruption on the power of the incentive scheme is ambiguous, since it depends on the type of corruption: (1) corruption in cost auditing or (2) corruption in information reporting. In the first case, accounting manipulation may be so severe that the social costs of implementing a rate-of-return policy (which implies relatively frequent reviews) are just too high. On the other hand, if corruption in information reporting is more relevant, a low-powered scheme is preferable as it reduces the stakes that parties could use in side-transfers.

The above argument assumes that the regulator is benevolent. If, on the other hand, the regulator can be captured by the firm, so that its objective function does not correspond to the social welfare function, it may choose price-cap in order to raise the informational rents that can be shared with the efficient firms. In such context, regulators would be underperforming (from the social welfare standpoint) by choosing price cap regulation more frequently than rate of return.

In summary, the negative coefficient on the corruption control variable may indicate either that the regulator is benevolent and the perceived high corruption in cost auditing leads it to choose price-cap regulation, or that the regulator is in fact *not* benevolent and chooses price-cap in order to raise the firms' rents.

Two variables reflecting the regulatory governance structure are also included in the probit regression. The first one measures the easiness of appealing the regulatory decisions; it is thus a proxy for accountability of the regulator. The second one is a dummy equal to one if the regulator is appointed for a fixed-term; it is supposed to be a proxy for the independency of the regulatory agency. The table shows that these variables are positive and statistically significant, which implies that better regulatory governance favours the adoption of price cap regulation.

Let us now proceed to the results of the single-equation stochastic production frontier. We are interested in three sets of results: the estimates of the technological parameters (the β's in our theoretical model), the impact of choosing price-cap compared to rate-of-return (the coefficient of ρ) and the estimates of the technological efficiency for each country (the θ's), which we discuss in the next subsection.

Dependent variable: Log of long-distance telephone minutes	(1)	(2)	(3)	(4)
Trend	0.0113 (0.984)	0.0051 (0.672)	0.0056 (0.727)	0.0169 (2.106)
Main telephone lines	1.0696 (21.967)	0.7901 (6.397)	0.7943 (5.857)	0.7347 (9.818)
Total telecommunications staff	-0.0083 (0.135)	0.4812 (4.663)	0.4785 (4.304)	0.5134 (7.081)
Price cap	0.1492 (1.749)	1.0568 (1.116)	1.0598 (1.043)	0.8165 (1.524)
Main telephone lines * Price Cap		0.3179 (2.436)	0.3136 (2.194)	0.3314 (4.225)
Total telecommunications staff * Price Cap		-0.5640 (4.905)	-0.5616 (4.543)	-0.5669 (7.019)
Theta * Price Cap			-0.0261 (0.955)	-0.0051 (0.192)
Reforma				-0.1328 (2.118)
Constant	6.2632 (25.589)	5.5649 (6.108)	5.5268 (5.520)	6.0849 (12.473)
Observations	192	192	192	192

Absolute value of z statistics in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 2: Stochastic production frontier

Table 2 shows that, when endogeneity of ρ is ignored, price-cap regulation has no statistically significant impact on the *level* of industry's production possibility frontier given the quantity of inputs. However, the interactions of the price-cap dummy with the inputs suggest that it affects positively the marginal productivity of capital (main telephone lines) and negatively the marginal productivity of labour (staff). Finally, there are increasing returns to scale when the industry is under rate-of-return regulation and constant returns under price-cap.

The next table presents the results from our simultaneous equations model estimated by the maximum likelihood method developed in section 3. The impact of price-cap regulation on the level of the production possibility set is, as before, positive, but now it becomes statistically significant and assumes considerably larger values. The interaction of the price-cap dummy with the inefficiency parameter also becomes significantly negative, implying that the higher the inefficiency of the industry, the lower the impact of a price-cap regime on production possibility set. The marginal input productivity changes from adopting price-cap, however, are not clear when the model is estimated simultaneously: the marginal productivity of capital now becomes lower, while the effect on labor is ambiguous.

Although the returns to scale estimates take quite different values as compared to the ones from the single equation model, the same general pattern arises: returns to scale are lower in countries that adopt a price-cap regime. This suggests that price-cap may be more appropriate in mature markets, where the network is more developed (returns to scale will presumably be lower in such situation). A rate-of-return policy provides more guarantees for the firm's return on investment than price-cap. Therefore, if regulators want to incentivize investment and network expansion (which is likely to be the case if returns to scale are high), then rate-of-return may indeed be the better option.

As for the policy choice equation, the coefficient estimates confirm the results from the single equation model. There is one additional result: the effect of θ can now be included on the policy choice. This is one very important benefit of our simultaneous model specification, since this was not possible to do when equations were estimated separately.

Particularly, we find that the higher the inefficiency of the industry, the higher the probability of choosing rate-of-return. Such confirms the theoretical predictions from Laffont and Tirole (1993). These authors demonstrate that regulators, in order to balance the trade-off between efficiency and informational rent, should assign high powered incentive regulation to the more efficient companies and low powered to less efficient ones.

	Coef.	*z*	*Coef.*	*z*	*Coef.*	*z*	*Coef.*	*z*	*Coef.*	*z*
Stochastic Frontier										
Trend	-0.0325	9.378	-0.0468	5.340	-0.0236	4.783	-0.0335	5.707	-0.0204	1.888
Line faults			-0.0927	4.289					-0.1339	3.877
Main telephone lines	2.4038	48.134	1.3760	6.006	1.3485	19.801	1.621	14.003	0.6586	5.768
Total telecom staff	-1.1284	20.928	0.1972	1.165	0.0881	1.371	-0.0073	0.071	0.1850	0.765
Price cap	9.0883	29.560	8.5965	4.684	5.2440	11.753	7.5189	10.429	1.2289	5.121
Main telephone lines * Price cap	-1.1323	21.944	-0.1414	0.722	-0.0535	0.878	-0.3163	2.896	-1.8919	1.212
Total telecom staff * Price cap	0.7464	13.624	-0.6605	4.664	-0.5071	7.812	-0.2883	2.884	1.0728	4.571
Theta * Price cap	-0.1125	8.973	-0.1598	8.924	0.2150	7.432	-0.0075	0.222	-1.4056	5.878
Reforma					0.0064	0.179			-7.9375	5.837
Policy Choice										
Political stability	1.5965	61.713	6.1561	71.453	2.0238	47.307	4.2978	92.806	5.3433	122.485
Corruption control	-0.5067	16.274	-3.5506	36.033	-1.3607	36.556	-2.7109	60.636	-2.7386	36.156
Regulator fixed term	1.2132	54.468	4.1777	67.213	1.6484	55.735	3.0143	64.419	3.8948	65.119
Tel. Subscribers / 100 inhabitants	-1.4448	72.499	-7.3170	47.810	-2.6805	70.511	-3.9839	87.865	-5.5734	97.724
Waiting list for telephone line	0.0077	0.526			-0.119	10.556	-0.1987	12.033		
GDP per capita			3.3639	24.723	1.5478	43.148	2.3906	46.700	3.1727	39.201
Theta	-3.2972	21.141	-15.5448	102.828	-3.0245	21.438	-13.3809	180.410	-20.3883	164.384
lnsig12	-2.6433	1.433	-14.1427	0.873	-15.0753	0.000	-17.8521	0.009	-17.0252	0.005
lnsig2v	-4.7811	2.149	-4.5844	18.324	-5.0601	23.565	-4.7642	21.738	-4.6886	13.562
lnsig2u	-0.3249	3.126	-0.3095	2.461	-0.7954	5.395	-1.1464	8.482	-1.2618	6.320
Observations	192		164		192		124		99	
Mean LL	-1.5334		-1.65842		-1.40404		-1.58754		-1.72752	
Sample	Full Sample		Full Sample		Full Sample		After Reform		After Reform	

Table 3: Simultaneous model

6 Efficiency Analysis

Graphs I and II in the appendix present the efficiency estimates and predicted probabilities of price-cap by country, ranked by regulatory regime and inefficiency. Because there is an interaction between the inefficiency parameter and the regulation dummy, the formula of the conditional inefficiency is slightly different from the usual production frontier model. In our model, the stochastic frontier's random term varies with the regulation: it is $\varepsilon_{it} = u_{2it} - c_{it}\theta_{it}$, where $c_{it} = 1 + (\gamma - 1)\rho_{it}$.

Given the distributions of u_2 and θ, the joint probability of (θ, ε) is (subscripts omitted):

$$f(\theta, \varepsilon) = \frac{1}{\pi \sigma_\theta \sigma_2} \exp\left(-\frac{\theta^2}{2\sigma_\theta^2} - \frac{(\varepsilon + c\theta)^2}{2\sigma_2^2} \right).$$

By computing the conditional distribution $f(\theta|\varepsilon)$, we are able to obtain the parameter of interest in production frontier studies, the conditional mean $E(\theta|\varepsilon)$:

$$E(\theta|\varepsilon) = \widetilde{\sigma}_* \left[\frac{\phi(\varepsilon\widetilde{\lambda}/\widetilde{\sigma})}{1 - \Phi(\varepsilon\widetilde{\lambda}/\widetilde{\sigma})} - \frac{\varepsilon\widetilde{\lambda}}{\widetilde{\sigma}} \right],$$

where $\widetilde{\sigma} = \sqrt{c^2\sigma_\theta^2 + \sigma_2^2}$, $\widetilde{\mu}_* = -\varepsilon c \sigma_\theta^2 / \widetilde{\sigma}^2$ and $\widetilde{\sigma}_* = \sigma_\theta \sigma_2 / \widetilde{\sigma}$.

We find that the countries that choose rate of return regulation present higher average inefficiency than countries choosing price cap regulation. We compare two estimates for the inefficiency: one from the sequential model, where the regulatory dummy is taken as endogenous, with the one from the simultaneous model. We find that, once we adopt the simultaneous specification, the estimates for the inefficiency are adjusted upwards among the countries adopting rate of return and downwards among countries adopting price cap. Nonetheless, we find countries such as Kenya and Uganda who's industry have a very high inefficiency level, that still are choosing Price Cap regulation.

Finally, the predictability of the model with respect to the choice of the regulatory regime improves considerably under the simultaneous model, especially for countries choosing rate of return. We have 3 out of 46 countries which attributes probability (slightly) below 50% for the actual regime.

7 Conclusion

The objective of this paper was to measure the performance of the telecommunications industry in a selection of developing countries, taking into account the policy choices by the regulatory agencies as well as the regulatory governance and the institutional endowments of the country. Previous literature exists analysing the relationship between regulatory regime and efficiency. The novelty of this study has been to explicitly take into account that the regulatory regime is itself an endogenous variable; in particular, we have argued that it is affected by institutional and governance factors that also have a direct influence on the firms' performance.

Our simultaneous equations model performs better than the single equations model with respect to the predictability of the regulatory regime and the estimated efficiency of the different countries. Additionally, our simultaneous equations estimation method allows us to include the inefficiency parameter from the production function on the equation describing the choice of regulatory policy.

The empirical results indicate that the probability of a regulator choosing price-cap increases with political stability and with the level of corruption, and decreases with the penetration rate. The result regarding the level of corruption is dubious, as it might be indicating either that the regulator is benevolent and it chooses price-cap in order to limit the effects of accounting manipulation, or that non-benevolent regulators are choosing price-cap in order to be able to share the higher informational rents. In the latter case, price-cap regulation would not be a favourable choice for consumers.

More importantly, we have confirmed the predictions of Laffont and Tirole (1993) that regulators offer a high-powered incentive scheme (such as price-cap) to more efficient firms, while offering a lower-powered scheme (such as rate-of-return) to inefficient firms.

We were able to get a measure of the actual effect of a price-cap regulation on output and efficiency, after controlling for possible endogeneity. It was shown that price-cap regulation increases the output frontier, but that the higher the inefficiency of the regulated firm, the lower the impact of price-cap regulation on the frontier.

Our study has taken fixed-line telephony regulation as the only policy issued by the national regulatory agency. Clearly, it is also the case that the regulator issues policies on other domains of the telecommunications sector, especially on the mobile telephone. Developing countries are experiencing an important growth of the number of mobile subscribers and sometimes, such service is being framed as substitute to fixed telephony. In this case, the regulator is choosing not only for the implementation of a mobile network but also the level of competition, through the licensing of a number of active mobile operators in the country. In such context, a more complete study on the impact of regulatory agencies on the telecom industries should take into account the actual bundle of policies issued by the regulator in the different domains of the industry.

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A Appendix

Table I: Wordbank Questionnaire: How are fixed-line prices regulated?

Type of Regulatory Policy	Nb of Countries	Countries	Assignment
Global Price Cap	3	Romania, Ivory Coast, Mexico	Price Cap
Price Cap	25	Argentina, Belize, Bolivia, Brazil, Bulgaria, Costa Rica, Czech Republic, Ecuador, El Salvador, Ghana, Honduras, Jamaica, Jordan, Kenya, Malawi, Mongolia, Pakistan, Panama, Peru, Slovak Republic, South Africa, Tanzania, Uganda	Price Cap
Rate of Return	2	Barbados, Moldova	Rate of Return
Other: Cost-orientation requirement	1	Greece	Rate of Return
Other: Incremental cost method	1	Chile	Rate of Return
Other: Pre-agreed price cap subject to annual revision	1	Venezuela	Rate of Return
Other: Standard tariff package is specified and it is mandatory to provide this package.	1	India	Rate of Return
Other: Tariff rebalancing process	1	Sri Lanka	Rate of Return
Other: Umbrella agreement	1	Latvia	Rate of Return
Other: Prices based on costs	1	Colombia	Rate of Return
Other: Prices constrained by a provision for affordability in the competition law	1	Poland	Rate of Return
None	5	Dominican Republic, Estonia, Guatemala, Turkey, Sao Tome and Principe	None
N/A	3	Morocco, Bosnia and Herzegovina, Thailand	N/A
Total	46		

Table II: Year of Relevant Privatization or Telecom Reform

Year	Nb of Countries	Cumulative Probability
1990	2	4.55
1991	1	6.82
1992	6	20.45
1993	3	27.27
1994	4	36.36
1995	6	50.00
1996	6	63.64
1997	4	72.73
1998	3	79.55
1999	1	81.82
2000	8	100.00
Total	44	

Table III: Impact of Reform and Regulatory Policy[a]

	Total telephone subscribers per 100 inhabitants			Cellular mobile telephone subscribers (Total)		
	Mean	Median	%	Mean	Median	%
Reform						
Before	19,365	14,395		3,75	1,034	
After	32,407	22,467	56%	18,001	8,893	760%
Rate of Return						
Before	27,204	15,039		5,796	1,866	
After	38,4	29,957	99%	17,179	6,199	232%
Price Cap						
Before	17,252	14,322		4,218	1,034	
After	24,674	15,447	8%	12,955	4,453	331%
No Regulation [b]						
Before	28,431	27,511		5,679	2,052	
After	39,608	27,492	0%	23,578	16,522	705%
N/A						
Before	6,185	6,059		1,124	0,019	
After	22,924	21,323	252%	13,383	9,934	52184%

Note (a) Based on first year of relevant reform.
(b) Countries that have informed having no regulatory regime on fixed line telephony have undergone telecom reforms.

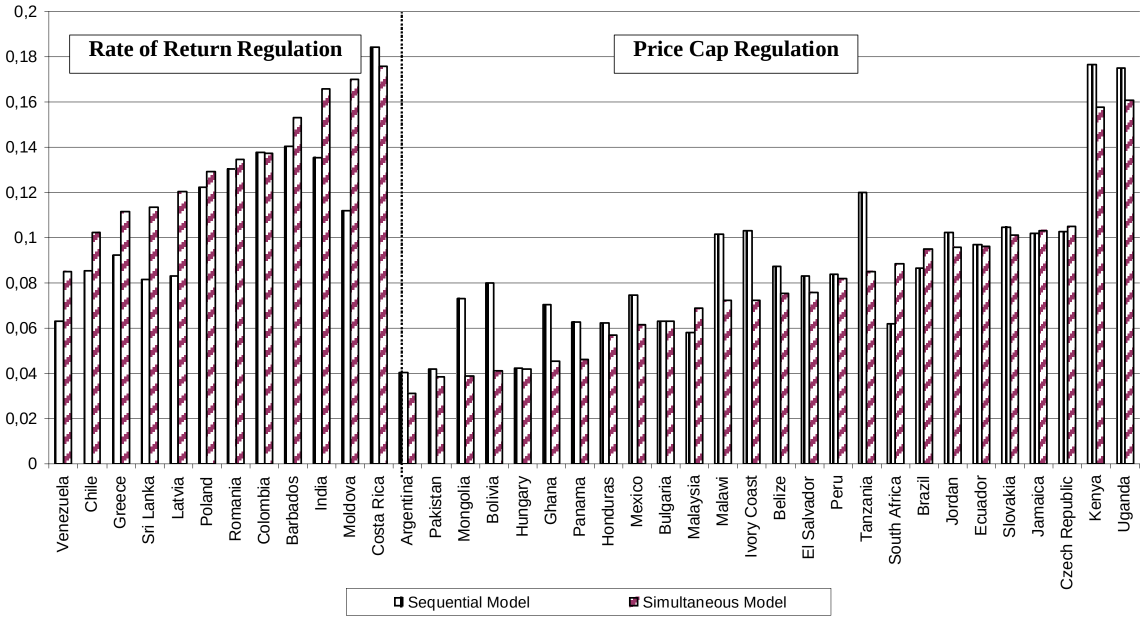
Table IV: Regulatory Regime and Institutional Indicators [a]

	Rate of Return	Price Cap	None
Voice and Accountability			
Mean	0,42964	0,14865	0,03933
Median	0,48722	0,22639	- 0,10228
Political Stability			
Mean	- 0,14084	0,00968	- 0,20242
Median	- 0,06168	0,07075	- 0,31389
Government Efficiency			
Mean	0,15547	- 0,11802	- 0,06811
Median	0,03936	- 0,15898	- 0,19616
Regulator Quality			
Mean	0,38973	0,24484	0,50319
Median	0,49985	0,22963	0,34833
Rule of Law			
Mean	0,18458	- 0,13547	- 0,10464
Median	0,21524	- 0,18947	- 0,05296
Control of Corruption			
Mean	0,04824	- 0,24656	- 0,18639
Median	- 0,15987	- 0,28055	- 0,31502

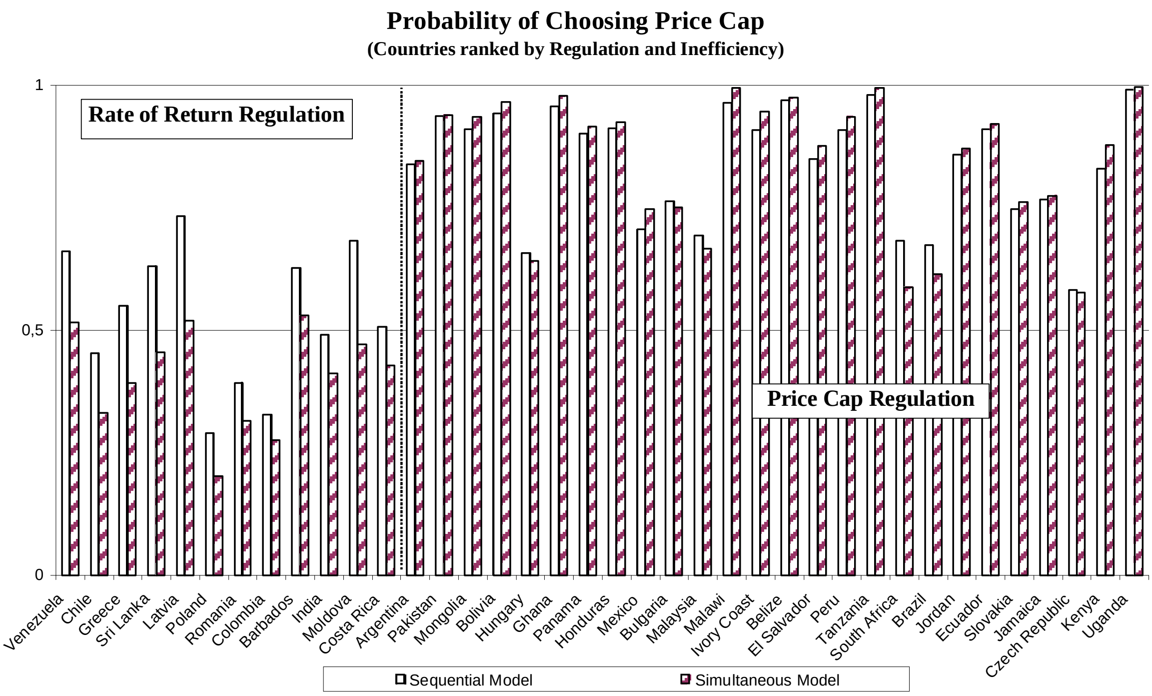
Note (a) Measures of government indicators proposed in Kaufmann, Kraay and Mastruzzi (2005), taking values from -2, 5 to 2,5.

Graph I

Countries Ranked by Regulation and Inefficiency



Graph II


Probability of Choosing Price Cap
(Countries ranked by Regulation and Inefficiency)
1
0,5
0
Rate of Return Regulation
Price Cap Regulation
Venezuela
Chile
Greece
Sri Lanka
Latvia
Poland
Romania
Colombia
Barbados
India
Moldova
Costa Rica
Argentina
Pakistan
Mongolia
Bolivia
Hungary
Ghana
Panama
Honduras
Mexico
Bulgaria
Malaysia
Malawi
Ivory Coast
Belize
El Salvador
Peru
Tanzania
South Africa
Brazil
Jordan
Ecuador
Slovakia
Jamaica
Czech Republic
Kenya
Uganda
Sequential Model
Simultaneous Model