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Regulatory regimes and efficiency in U. S. local telephony

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Marcelo Resende

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Abstract

The paper aims at assessing the efficiency consequences of different regulatory regimes for U.S. local telephony. Specifically one contrasts alternative regulatory regimes (price-cap regulation and incentive regulation) with traditional rate-of-return regulation. Relative efficiency scores are obtained from the Data Envelopment Analysis (DEA) approach. The regression analysis on the determinants of efficiency indicates, after controlling for technical change effects, that alternative forms of regulation appear to induce a higher level of efficiency for the regulated firms.

Resumo

O artigo pretende avaliar as consequências em termos de eficiência dos diferentes regimes regulatórios para telefonia local nos E.U.A. Especificamente, contrasta-se regimes regulatórios alternativos (regime de limitação de preços e regulação por incentivos) com a tradicional regulação da taxa de retorno. Indicadores de eficiência relativa são obtidos a partir da abordagem da Análise Envoltória de Dados (DEA). A análise de regressão acerca dos determinantes da eficiência indica, após controlar para efeitos referentes a progresso técnico, que as formas alternativas de regulação parecem induzir a um nível mais elevado de eficiência por parte das firmas reguladas.

1. Introduction

The literature on regulatory issues has grown at a fast rate during the eighties, especially in terms of its theoretical developments. In particular, there has been an increasing recognition of the informational constraints characterizing the regulatory relationships (See eg. Baron, 1989, and Laffont & Tirole, 1993). The theoretical treatment of the basic variants of asymmetric information (adverse selection and moral hazard) has increased our knowledge of optimal incentive regulation schemes, but there is still a gap in what concerns empirical assessments of alternative regulatory regimes. It is consensual that the traditional rate-of-return (ROR) regimes do not provide the adequate incentives for efficiency, both from a static or dynamic perspective. It is not clear, on the other hand, whether actual forms of alternative regulation (profit or revenue sharing, price-caps) will substantially differ from the traditional form of regulation. The previously examined arguments concerning a comparative assessment of regulatory regimes are mixed. In fact, authors as Beesley & Littlechild (1989) and Liston (1993) provide descriptive lists of positive and negative aspects of the alternative regimes. The present paper intends to start filling the gap in the empirical literature by assessing the efficiency consequences of alternative regulatory regimes, taking as reference the local telephony in the U.S. The referred sector provides a "laboratory" for comparing distinct forms of regulation as state level regulatory regimes displayed a large variability. Comparative assessments of alternative regulatory regimes are essentially absent. Mathios & Rogers (1989) constitute an exception by considering reduced form procedures to analyse long-distance pricing under ROR and price-cap regulation (PCR). The authors find support for lower prices under PCR. Nevertheless a detailed and flexible evaluation of the efficiency consequences of alternative forms of regulation was still needed. The paper is organized as follows. The second section presents the main classes of regulatory regimes and provide a description of the evolution of the different forms of regulation in the context of U.S. local telephony. The third section provides a brief digression on the technique of Data Envelopment Analysis (DEA), which is used for constructing empirically determined efficiency frontiers. The related empirical results are presented and discussed. The fourth section discusses the determinants of the efficiency level in local telephony, stressing in particular the role of alternative formas of regulation. Finally, the fifth section brings some final comments.

2. Regulatory Regimes: an Overview

A crucial role attributable to a regulator has to do with providing the appropriate incentives for productive efficiency by the regulated firm in both static and dynamic terms. The first aspect is closely related to mitigating the problem of moral hazard by means of reductions of avoidable wastes. The second aspect, on the other hand, involve incentives for cost reduction in the long run. For example, one could refer to research and development (R&D) expenditures with the purpose of improving the intrinsic efficiency level of the regulated firm and therefore the issue relates to the problem of adverse selection in regulatory interactions. A central issue is then to verify to what extent the regulatory regimes prevailing in the real world lead to proper levels of

efficiency. One should keep in mind, that ultimately one is trying to emulate the incentive mechanisms present in competitive markets. It appears to exist a consensus that one should let the market work, whenever it is potentially competitive (See eg. Baumol & Sidak, 1994). But in sectors with natural monopoly characteristics, the regulator is expected to play the role of providing the adequate incentives for the regulated firm. Let's consider therefore the different forms of regulation.

In general terms, one can refer to three broad classes of regulatory regimes. The first is the traditional ROR, according to which the regulator establishes a "fair" rate-of-return that the regulated firm would be allowed to earn. Besides well known distortions such as the Averch-Johnson effect, the regime of ROR is reputed to provide low incentives for cost reduction.

A second broad category refers to price-cap regulation (PCR) also known as RPI-X. This mechanism intends to put regulation in the "automatic pilot" and would have an explicit concern for efficiency given the productivity off-set X. Some authors attempted to provide a comparative assessment of the aforementioned regulatory regimes (See eg. Vickers & Yarrow 1988, Beesley & Littlechild 1989 & Liston, 1993). Nevertheless, it does not appear to emerge definitive arguments on the clear superiority of PCR over ROR.[1] In fact, an important issue refers to the exogeneity of the X factor. Ideally it should possess a forward looking character. In practice, however, one tends to consider backward looking criteria often based in the calculation of total factor productivity measures. The endogenous character of the X factor can in principle induce a ratchet effect, according to which a firm would like to appear as less efficient in order to secure more favourable tariff levels in the future. In face of this type of argument, one could be concerned on whether PCR differs much from the ROR regime with regulatory lag. Moreover, some analysts contend that the PCR regime has been especially lenient with the regulated firm, allowing large profits by means of low X factors (See Mayer & Vickers, 1996). In this sense, a third broad category of regulatory regimes has gained force, especially in the U.S., namely the so called incentive regulation (IR). This category basically encompasses two basic variants (See eg. Benedict et al. 1996). A first modality is the banded rate-of-return regulation (BROR) whereas a second one refers to the banded rate-of-return with earnings sharings (BRORES). The latter modality is indeed the most common in the context of IR and essentially consists of a modified ROR regime, under which (unlike the former) earnings are shared (typically revenues) when one exceeds the reference rate-of-return band. This regulatory regime is believed to provide incentives for cost reduction as the regulated firm can appropriate (partially) the benefits accruing from its cost reduction efforts (See Blackmon, 1994).

The local telephony in the U.S. is gradually being subject to alternative forms of regulation, comprising both PCR and IR regimes. Next we construct a regulatory regime variable. For that purpose we relied on information dispersed in documents from the National Regulatory Research Institute (NRRI), National Association of Regulatory Utility Commissioners (NARUC) and the public utility commissions of the 50 states.[2] The coexistence of traditional and alternative forms of regulation in different states of the U.S. provides a unique opportunity for a comparative assessment of regulatory regimes. The efficiency measurement and econometric analyses to be undertaken in subsequent sections have as basic source the *Statistics of Communication Common Carriers (SCCC)* published annually by the Federal Communications Commission (FCC). This source comprises balance sheet and telephone plant account data, which in some cases revealed to be incomplete, requiring thus the consultation

of unpublished documents that form the basis for the construction of the SCCC, namely the so called ARMIS 43-08. The idea was then to generate the longest consistent sample of local exchange carriers (LECs) for which reliable data was available. Our interest is concentrated over the period 1988-94. In fact, the accounting system changed in 1988. Moreover, incentives for local telephony competition started appearing by the end of that sample period. In that sense, the chosen sample period will allow to isolate the regulatory regime effect. An important operational issue has to do with the fact that usually LECs operate in different states, whereas we have state level regulation information. In that sense, we considered firm data at state level on the number of local loops, to proxy the state weight of firm's activity, the referred data was obtained from the *Monitoring Report* of the FCC. The regulatory regime variable can be interpreted as the proportion of the LEC's activity which was subject to *alternative forms of regulation* in contrast with *traditional ROR*. A finer characterization would not have been possible, given the available information and the fact that different alternative regimes sometimes coexisted for different services of a given LEC. The regulatory regime variable is presented in table 1 for the largest consistent sample that was possible to generate.[3]

Table 1
Regulatory Regime Variable

LEC	1988	1989	1990	1991	1992	1993	1994
Bell-IL	0	0	0	0	0	0	0
Bell-IN	0	0	0	0	0	0	0.417
Bell-MI	0	0	0	0	1	1	1
Bell-OH	0	1	1	1	1	1	1
Bell-WI	1	1	0	0	0	0	1
CP	0	0	0	0	0	1	1
CP-MD	0	0	0	0	0	1	1
CP-VA	0	1	1	1	1	1	1
CP-WV	1	1	1	1	1	1	1
Diamond	0	0	0	0	0	0	0.833
Bell-PA	0	0	0	0	0	0	0.583
Bell-NJ	1	1	1	1	1	1	1
CE-FL	0	0	0	0	0	0	0
CE-VA	0	1	1	1	1	1	1
Cinc.Bell	0	0	0	0	0	0	0
CO-CA	0	0	0	0	0	0	0
CO-TX	0	0	0	0	0	0	0
GTE-CA	0	0	1	1	1	1	1
GTE-FL	0	0	0	0	0	0	0
GTE-HI	0	0	0	0	0	0	0
GTE-No	0.046	0.048	0.046	0.044	0.202	0.202	0.311
GTE-SO	0.062	0.089	0.088	0.214	0.210	0.210	0.085
GTE-Sw	0	0	0	0	0	0	0
Lincoln	1	1	1	1	1	1	1
N.Eng.	0	0.245	0.247	0.247	0.247	0.246	0.197
N.York	0	0	0	0	0.167	1	1
Nev.Bell	0	0	0	0.5	1	1	1
Pac.Bell	0	0	1	1	1	1	1
SE. N.E.	0	0	0	1	1	0.583	0
SW.Bell	0	0	0.257	0.255	0.253	0.252	0.087
Carolina	0	0	0	0	0	0	0
UT-SE	0	0.318	0.317	0.315	0.313	0.311	0.311
UT-FL	0	0	0	0	0	0	0
UT-MO	0	0	0	0	0	0	0
UT-OH	0	0	0	0	0	0	0
UT-PA	0	0	0	0	0	0	0.5

Note: the variables are scaled by the number of months in the year that the alternative form of regulation was in place.

The inspection of the previous table indicates, as mentioned before, that one can observe a gradual movement away from traditional ROR. Nevertheless, one can observe in some cases a return to the ROR regime. Having characterized the regulatory regimes in U.S. local telephony we should proceed in the next section with a efficiency measurement exercise so as to prepare the ground for evaluating the role of alternative regulatory regimes in enhancing the efficiency level of the regulated firms, an issue that will be addressed by means of a econometric analysis considered in the fifth section.

3. Efficiency Evaluation and Data Envelopment Analysis

3.1 Introduction

A common approach to evaluate efficiency in local telephony involves the consideration of cost functions. Two major pitfalls of that approach are noteworthy. First, flexible cost functions are usually evaluated in their expansion point at mean values.[4] This simplification can be problematic in the case where significant heterogeneity is present across distinct firms in the sample.[5] A second caveat has to do with the cost minimization assumption embodied in cost function estimation. The presence of a moral hazard problem in terms of avoidable wastes can place firms somewhat distant from the efficiency frontier, in the real world.[6]

In the present section we consider the flexible approach of Data Envelopment Analysis (DEA) to obtain an efficiency frontier for the LECs. DEA differs from traditional econometric analysis in two important aspects:

a) The production efficiency frontier is obtained in a nonparametric fashion, as the solution to a fractional linear programming problem;

b) The core point is the assessment of relative efficiencies. This approach constrasts with traditional econometric methods which emphasize average planes that would be adjusted and assumed to hold for each decision making unit (DMU) (See eg. Seiford & Thrall, 1990).

The seminal paper of Leibenstein (1966) considered the possibility of a non-allocative form of inefficiency, the so called x-inefficiency. A possible explanatory factor would be related to sub-optimal effort levels in the context of a principal-agent relationship. Frantz (1988, 1992) and Leibenstein & Maital (1992) suggest the DEA approach as a relevant tool for measuring the referred inefficiency.

The DEA approach has been object of numerous applications in different areas (Seiford, 1994, compiles a vast and diverse bibliography). Moreover, the reader can find useful introductions to the topic in Boussofiane et al. (1991), Chang & Sueyoshi (1991) and Charnes et al. (1994), among others.

The main appeal of the DEA approach refers to its flexibility. In fact, such technique imposes no functional forms restrictions on the underlying technology, other than convexity and piece-wise linearity of the technology. The DEA approach can be thought as a multi-output and multi-input extension of the empirically determined efficiency frontiers initially proposed by Farrell (1957). The first influential DEA model was introduced by Charnes, Cooper & Rhodes (CCR, 1978) and contemplated the constant returns to scale case. Banker, Charnes & Cooper (BCC, 1984) extended the CCR model in order to allow for variable returns to scale. The BCC model will be adopted in our empirical analysis, and can be described as an extension of the CCR model which is presented next. We consider m inputs (indexed by subscript i), s

outputs (indexed by subscript r) and n DMUs (indexed by subscript j). Furthermore, it is assumed that $x_{ij} > 0$ and $y_{rj} > 0$. The CCR can be thought in terms of the comparison of a virtual output with a virtual input, subject to some constraints. Specifically, CCR considers the follwing fractional programming problem, which should be solved for each DMU:

$$\max_{u,v} h_k = \sum_{r=1}^{s} u_r y_{rk} \Big/ \sum_{i=1}^{m} v_i x_{ik} \qquad (1)$$

subject to:

$$\sum_{r=1}^{s} u_r y_{rj} \Big/ \sum_{i=1}^{m} v_i x_{ij} \le 1 \ (\text{for } j = 1,2,\dots,k,\dots,n) \qquad (2)$$

$$u_r > 0 \ (\text{for } r=1,\dots,s) \quad v_i > 0 \ (\text{for } i=1,\dots,m) \qquad (3)$$

The program above constitutes a fractional linear programming problem where one introduce two restrictions. The first one indicates that no DMU can operate beyond the efficiency frontier (restriction 2), whereas the second one imposes that the weights should be positive (restriction 3). The previous problem can be transformed into a conventional linear programming problem, as shown by CCR (1978), leading to:

$$\max_{u,v} w_k = \sum_{r=1}^{s} u_r y_{rk} \qquad (4)$$

subject to:

$$- \sum_{i=1}^{m} v_i x_{ij} + \sum_{r=1}^{s} u_r y_{rj} \le 0 \text{ (for } j = 1,\dots,n) \qquad (5)$$

$$\sum_{i=1}^{m} v_i x_{ik} = 1 \qquad (6)$$

$u_r > 0$ (for $r = 1,\dots,s$) $\quad v_i > 0$ (for $i = 1,\dots,m$) (7)

Since the previous program constitutes a standard linear programming problem, it admits a dual representation, which is given by:

$$\min \quad \theta \qquad (8)$$

subject to:

$$- \sum_{j=1}^{n} x_{ij}\lambda_j + \theta x_{ik} \ge 0 \text{ (for } i = 1,\dots,m) \qquad (9)$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j \ge y_{rk} \text{ (for } r = 1,\dots,s) \qquad (10)$$

$$\lambda_j \ge 0 \text{ (for } j = 1,\dots,n) \qquad (11)$$

A limitation associated with the CCR model just described is the assumption of constant returns. BCC (1984) and Banker (1984) extended the CCR model so as to incorporate the possibility of variable returns to scale. The notion of variable returns can be defined in terms of the production possibility set , which is defined as T= {(X,Y): the output vector Y ≥ 0 can be produced from the input vector X ≥ 0}. Returns to scale at a point (X, Y) on the efficient surface of T would be in terms of r described below:

$$\rho = \lim_{\beta \to 1} \frac{\alpha(\beta) - 1}{\beta - 1} \qquad (12)$$

where a (b) = max {a: (bX, aY) ÎT}, b > 0.

The previous expression would indicate how proportionate changes in the input vector reflect in terms of changes in the output vector. r > 1, r< 1 and r = 1 would respectively indicate increasing, decreasing and constant returns to scale. Additionally, one can define the concept of a most productive scale size (mpss) that would represent the most efficient scale for given input and output mixes. An influential result obtained by Banker (1994) is that aggregate efficiency score (obtained from the CCR model) is equal to the technical efficiency score (obtained from the BCC model) multiplied by the scale efficiency score.

Finally, one should consider the form by which the BCC model extends the CCR model. Essentially, a convexity restriction is added to the CCR formulation summarized by equations 8-11. More specifically, convexity requires that if $(X_j, Y_j) \in T$ for $j = 1,\dots, n$ and $\lambda_j \ge 0$ are non-negative scalars such that $\sum \lambda_j = 1$, then $(\sum \lambda_j X_j, \sum \lambda_j Y_j) \in T$. The BCC model appends the restriction $\sum \lambda_j = 1$ to the problem described by equations 8-11. Sawkins and Accam (1994) emphasize that the usefulness of convexity is to secure that any composite unit extrapolated is similar in size to the reference unit and not merely an extrapolation of another composite unit operating at a different scale size. The convexity restriction guarantees that all DMUs are considered with reference to linear combinations of inputs and outputs.

Having briefly described the BCC model, it is important to further motivate the application of that approach in the context of U.S. local telephony. One should once more emphasize the flexibility of the approach. This provides an extra motivation as we can partially bypass some measurement error issues associated with cost function estimation. For example, the measurement of input prices (especially price of materials appears to be problematic), but the DEA approach does not require the knowledge of input prices.

One could in principle question the use of DEA instead of stochastic efficiency frontiers. The literature on that topic is often criticised for its strong distributional assumptions. One typically assumes that the error term has two components, where the component reflecting the efficiency level would possess a truncated distribution, for example half normal. Even though the distributional assumptions are somewhat less strict in the context of panel data (See eg. Atkinson and Cornwell (1993)], it would be required a large number of years in order to obtain consistent estimators. In the present application the data spreads , however, over a period of only 7 years. Moreover, Banker (1993) provides a formal statistical basis for the efficiency evaluation using DEA. If one treats the deviations of the DEA scores (obtained from the BCC model) from the efficient level as stochastic variables, then a monotone decreasing probability density function for these deviations is a sufficient (and almost) necessary condition for the DEA scores maximize the likelihood of obtaining the actual sample of observations. In the stochastic frontier literature that would be true only if the inefficiency distribution is exponential or half-normal (See eg. Aigner & Chu, 1968). In that sense, DEA possesses a maximum likelihood motivation under less strict assumptions than the stochastic frontier literature. Next we consider the application of DEA to U.S. local telephony.

3.2 Empirical Results

Majumdar (1995) consists of the only previous study employing DEA techniques in the telecommunications sector. Other applications exploring the usefulness of this "relative efficiency" approach in regulated settings appear in Sawkins and Accam (1994) who considered the assessment of comparative efficiency in the Scottish water industry. Majumdar's paper considered pre and post- divestiture periods ranging from 1973 to 1987. The main motivation of that paper was to evaluate the efficiency gains in an increasingly more competitive environment. It should be noted however, that neither firm specific competition variables nor general competition regime variables are used in the study, In that sense, the paper is more properly interpreted as an efficiency measurement exercise. In the present paper, we make use of the same variables definitions used by Majumdar. An important attribute in empirical applications of DEA models is that of parsimony. In fact, the larger the number of inputs and outputs considered, the larger the number of dimensions on which different LECs can appear as relatively efficient. If one considers an extensive list of inputs and outputs the discrimination between different DMUs would become blurred. In the present application we will consider 3 inputs and 3 outputs as follows:

. **outputs:** deflated figures for local services revenues, long distance revenues and total access and other revenues. The 3 categories of revenues were deflated respectively by the consumer price index for local telephone services, the consumer price index for intrastate toll telephone services and the overall consumer price index for telephone services. The revenue data was obtained from the SCCC published by the FCC, whereas the consumer price indexes were obtained from the *Statistical Abstract of the U.S. (Bureau of the Census - U.S. Department of Commerce)*

. **inputs:** total number of employees, total number of access lines and total number of central office switches. The basic data source was the SCCC from the FCC, complemented by the ARMIS 43-08 when it was necessary.[7]

The BCC model was applied for each year in the period 1988-94. The related technical efficiency scores are presented in table 2. It should be noted that the DEA models admit two orientations output augmentation (output orientation) and input conservation (input orientation). In the former, efficiency refers to obtaining the maximum output level given a fixed utilization of inputs; the latter orientation, on the other hand refers to the minimum use of inputs for a given level of output. In actual empirical implementation the choice of orientation is usually not crucial, in the present case it does not make virtually any difference. The results presented in the next table nevertheless refer to the input orientation, which is consistent with the usual interpretation of exogenous outputs (often assumed in the context of cost function estimation in regulated industries).

Table 2
Technical Efficiency (Variable Returns to Scale-Input Orientation)

LEC	1988	1989	1990	1991	1992	1993	1994
Bell-IL	85.89	85.13	88.83	82.66	85.69	88.92	93.66
Bell-IN	90.79	90.08	89.09	90.63	87.89	94.39	100.00
Bell-MI	98.78	100.00	95.83	92.10	93.05	88.62	95.05
Bell-OH	97.57	98.29	99.18	95.54	95.87	100.00	100.00
Bell-WI	93.25	85.88	89.56	93.67	94.28	96.54	96.65
CP	100.00	100.00	100.00	100.00	100.00	100.00	100.00
CP-MD	87.99	90.90	98.73	98.20	100.00	94.07	100.00
CP-VA	100.00	100.00	100.00	100.00	100.00	100.00	100.00
CP-WV	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Diamond	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Bell-PA	100.00	100.00	100.00	100.00	98.22	94.60	95.81
Bell-NJ	100.00	100.00	100.00	100.00	100.00	100.00	100.00
CE-FL	100.00	100.00	100.00	78.29	74.42	73.68	81.95
CE-VA	94.19	96.42	98.12	100.00	100.00	100.00	100.00
Cinc.Bell	100.00	100.00	100.00	100.00	100.00	98.89	98.97
CO-CA	100.00	100.00	100.00	100.00	100.00	100.00	100.00
CO-TX	100.00	100.00	100.00	100.00	100.00	100.00	100.00
GTE-CA	100.00	100.00	100.00	100.00	100.00	100.00	100.00
GTE-FL	100.00	93.26	91.45	100.00	99.83	81.58	94.19
GTE-HI	100.00	100.00	100.00	100.00	100.00	100.00	100.00
GTE-No	100.00	100.00	100.00	100.00	100.00	100.00	100.00
GTE-SO	87.74	91.35	100.00	100.00	100.00	100.00	100.00
GTE-Sw	100.00	100.00	100.00	100.00	99.94	81.77	100.00
Lincoln	84.40	88.34	90.73	97.29	100.00	100.00	100.00
N.Eng.	96.11	98.02	94.46	95.07	90.85	94.97	94.22
N.York	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Nev.Bell	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Pac.Bell	100.00	100.00	100.00	100.00	100.00	100.00	100.00
SE. N.E.	87.80	96.52	94.37	97.84	100.00	100.00	100.00
SW-Bell	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Carolina	68.12	66.13	68.18	83.46	73.00	92.42	98.18
UT-SE	89.71	94.70	95.88	97.37	87.27	99.78	88.27
UT-FL	100.00	100.00	100.00	96.28	90.46	77.55	100.00
UT-MO	100.00	100.00	100.00	100.00	100.00	100.00	100.00
UT-OH	81.93	81.16	84.30	80.60	84.22	81.78	97.93
UT-PA	77.82	78.57	59.81	71.94	75.89	78.43	82.17

The next table presents the results from Wilcoxon tests to verify the existence of significant changes in the mean efficiency scores across different years.

Table 3
Wilcoxon Test Results on Comparison of Selected Years (BCC Model)

	Years Compared			
	1988	1991	1991	1994
Mean	95.06	95.85	95.85	97.70
Test Statistic	-0.6864	-2.0686		
P-Value	0.4925	0.0386		

The tests indicate that the mean level of technical efficiency have not significantly increased between 1988 and 1991. The comparison between 1991 and 1994 reveals a different picture with a significant increase in the mean efficiency level of the sector. A natural question that arises is to which extent that improvement in the efficiency level merely reflects technical changes observed in telecommu-nications and to which extent it is driven by changes in the forms of regulation. We address those issues in the next section where a econometric analysis on the determinants of efficiency is undertaken.

4. Determinants of Efficiency: Econometric Evidence

The general setup of the DEA approach considers variables directly related to inputs and outputs, but of course there may be other variables, often outside the firm's discretion, that might play an important role in explaining the efficiency level of the DMU. The role of the "reduced form" analysis of this section is exactly to consider those variables.

The range of efficiency scores obtained from DEA models in censored and therefore a simple application of OLS may produce biased estimates if there is a significant portion of the observations which are equal to one. In fact, this is the case as seen before. A possible strategy is to estimate a Tobit model (See Maddala, 1983, for details). In order to conform with the left censoring, one can adopt the reciprocal of the technical efficiency score. Moreover the referred variable can be transformed so as to conform with the zero censoring point assumed in the traditional Tobit frormulation. [8] In this sense, the dependent variable is an inverse measure of efficiency. The underlying efficiency score is a technical efficiency measure obtained from the BCC formulation, so there will be no need for concerns on controlling for scale effects in the subsequent reduced form regressions. One has to be concerned, however, on separating effects arising from technological change in telephony and influences pertaining regulatory effects. It is important therefore to understand in general lines recent technical changes in the telecommu-nications sector.

In broad terms the telephone sector can be summarized by means of two large categories: network facilities and services provided over such network. The network comprise basically transmission facilities, switching facilities and terminals. All these categories experienced substantial change, most importantly:

- **transmission technology:** at end user level, traditional technologies continue to prevail with local loops characterized essentially by copper wiring. In fact, the main changes in transmission technology relate to the improvement of radio based transmission and introduction of fiber optic components in trunk cables. A main development has been the substitution of the older generation of high capacity cables by fiber optic cables; an associated improvement has been the digitization of the network, by which the signals are transmitted in a digital form instead of the previously prevalent analogue mode. Apart from the increase in the transmission quality, these developments have the following important consequences to be emphasized: i) possibility of provision of broad band services, in particular, potential for transmission beyond the traditional voice based services (eg. video, data). The new transmission technology can transmit substantially larger amounts of information at higher speeds; ii) less need for intermediate signal amplifiers and smaller maintenance costs.

. **switching technology**: the major recent development concerns the use of switching facilities controlled by computer systems [the so called stored program control (SPC); the main advantages that follow have to do with the relatively easier maintenance and reconfiguration. Additionally, rerouting of calls starts becoming possible; however, it is believed that the cost of exchanges and the associated softwares is not falling as fast as those pertaining transmission [See Armstrong et. al. (1994)].

The discussion above, points out two main categories of technical change: those related with transmission technology and those associated with switching technology. In practice, changes in transmission technology are likely to have a deeper effect in the interexchange carriers - IXCs [like AT&T, MCI and Sprint] than in the local exchange carriers (LECs). Nevertheless, one is increasingly observing the introduction of fiber optics in trunk cables of the LECs. Taking as reference the previous observations we consider the empirical construction of variables proxying technical change, these will operate as control variables in the the econometric analysis of the determinants of efficiency in U.S. local telephony. We consider a composite indicator of innovation by means of factor analysis.[9] Specifically, we considered three variables: research and development (R&D) expenses deflated by the GNP implicit price deflator, percentage of main access lines that are digital (DIG) and miles of fiber deployed in cable divided by the total miles of cable (FIB). The factor analysis method allowed to explore common dimensions on that data set. The factor structure was chosen according to the usual criterion of retaining the factors for which the related eigenvalues of the correlation matrix was greater than one (See Kaiser, 1974). This allowed us to retain a single factor, for which the factor scores were saved for further use as the INOV variable. In fact, the use of factor analysis to develop composite indicators of innovation has appeared in the specialized literature (See eg. Hollenstein, 1996).[10]

In addition to technical change variables, it may be important to control for density effects. In fact, as suggested by Shin and Ying (1992) and Ying and Shin (1993), geographical aspects may be important. In that sense, in a similar vein as those authors, we consider the average loop length (AL) defined by total miles of cable divided by the total number of access lines. For example, companies operating mostly over dispersed localities would in principle be in relative disadvantage in comparison to firms operating in highly densed regions.

Next in table 4, the empirical results are presented for a first specification (model 1).[11]

Table 4

Technical Efficiency Regression Results-Tobit Model (252 observations)-
Model 1

Variable	Coefficient	Standard Error	t Statistic
Constant	0.0068	0.0262	0.2583
INOV	-0.0607	0.0199	-3.0504
REG	-0.0922	0.0350	-2.6348
AL	-0.8318	0.5557	-1.4968
σ	0.1849	0.0143	12.8933
Log-likelihood	-55.1183		

All variables display the expected signs, except for the density variable AL. The related coefficient is not however significantly different from zero. In particular, one obtains a negative and significant coefficient for the regulatory regime variable REG. It appears, therefore, that alternative forms of regulation as contrasting with traditional rate-of-return regulation does play some role in inducing a higher level of efficiency in the local telephony sector. Before concluding, we consider an alternative specification (model 2), where we additionally include the variable PCAP in the regression. The referred variable is a dummy assuming value 1 from 1991 onwards, following the introduction by the FCC of price-cap regulation for interstate switched access (See FCC, 1989, 1990). The corresponding results appear in the next table.

Table 5

Technical Efficiency Regression Results-Tobit Model (252 observations)-
Model 2

Variable	Coefficient	Standard Error	t Statistic
Constant	-0.0082	0.2978	-0.2746
INOV	-0.0682	0.0213	-3.2045
REG	-0.0948	0.0349	-2.7080
AL	-0.9117	0.5631	-1.6191
PCAP	0.0324	0.2936	1.1038
σ	0.1844	0.0143	12.8985
Log-likelihood	-54.5057		

The inclusion of PCAP does not therefore alter the previous conclusions, and the evidence once more indicates that part og the efficiency improvement in the recent years can be attributed to more favourable incentive properties ensuing from alternative forms of regulation.

5. Final Comments

The purpose of the present paper was to to provide a careful empirical analysis for comparing the efficiency consequences of distinct regulatory regimes in telecommunications. The sector in question provides a very favourable environment for such type of study, as regulation is largely determined at state level.

The flexible approach adopted for determining the efficiency frontier explictly considered the possibility that some firms do not operate in the efficiency frontier. In fact, it is expected that avoidable wastes are likely to exist. The subsequent econometric analysis attempted to separate technical change and regulatory effects and concluded that alternative forms of regulation induces a higher level of productive efficiency as contrasted with traditional ROR. The present paper may be seen as a first effort on filling the gap in the empirical literature on regulation. Nevertheless, one should expect more studies on the topic to appear in the future. But, in any case, a finer characterization of regulatory regimes appear to be especially difficult. In that sense, an evaluation of the relative efficiency merits of PCR and IR appears to be very complex, but will be a priority in the research agenda on empirical aspects of regulation, especially as traditional ROR becomes less prevalent.

Appendix

List of Local Exchange Carriers Included in the Sample

1) Bell - Illinois

2) Bell - Indiana

3) Bell - Michigan

4) Bell - Ohio

5) Bell - Wisconsin

6) Chesapeake & Potomac

7) Chesapeake & Potomac - Maryland

8) Chesapeake & Potomac - Virginia

9) Chesapeake & Potomac - West Virginia

10) Diamond

11) Bell - Pennsylvania

12) Bell - New Jersey

13) Centel - Florida

14) Centel - Virginia

15) Cincinatti Bell

16) Contel - California

17) Contel - Texas

18) GTE - California

19) GTE - Florida

20) GTE - Hawaii

21) GTE - North

22) GTE - South

23) GTE - Southwest

24) Lincoln

25) New England

26) New York

27) Nevada Bell

28) Pacific Bell

29) Southern New England

30) Southwestern Bell

31) Carolina

32) United - Southeast

33) United - Florida

34) United - Missouri

35) United - Ohio

36) United - Pennsylvania

Notas

1 For a discussion on other pitfalls of the PCR regime, see Isaac (1991) and Loube (1994).

2 The telephony sector in the U.S. is subject to a two level (state and federal) regulation. For further details on the related institutional arrangements see Mitchell & Vogelsang (1991).

3 The regulatory regime variable was constructed so as to match the selected LECs for the efficiency measurement analysis. A complete list of the firms indicated in table 1 appears in the appendix.

4 A recent application of translog cost function estimation to U.S. local telephony appears in Ying & Shin (1993). Banker, Conrad & Strauss (1986) provided a comparative assessment of DEA and translog cost function for hospitals stressing that the heterogeneity issue can be important..

5 This is indeed the case in the U.S. Local Telephony, as the translog cost function estimation by Resende (1997) indicated.

6 Anecdotal evidence from FCC officers indicates that some regulated firms stopped paying first class airline tickets after the regulatory regime changed from ROR to PCR.

7 The reliance on deflated revenues reflect the fact that consistent data on the number of telephone calls were not available for the whole sample period. In the input side we are however able to fully explore the flexibility of the DEA method by making use of "physical" variables.

8 A similar procedure was adopted by Dusansky and Wilson (1994) and Pollit (1996).

9 The factor model postulates a p dimensional characteristics random vector X, with mean μ and covariance matrix E, can be linearly associated with two classes of unobserved factors: the m dimensional common factors vector F (m < p) and a p dimensional specific vector e, which explains variation only of a single 'specific' component of X. The factor model can be compactly expressed by:

$X-\mu = LF + e$, where L denotes the (p x m) matrix of factor loadings, and Cov $(F_i, e_i) = 0$ for i = 1:p. See Morrison (1990) for further details.

10 The subsequent analysis makes use of the just mentioned composite measure of innovation. The results from the econometric analysis were similar even if one had made use of the fiber optics variable (FIB).

11 The Tobit model is usually applied in a cross-sectional context, but it is fortunate to know that even in the case of the eventual presence of serial correlation, the Tobit model retains its consistency property (See Robinson, 1982).

References

AIGNER, D. J. and S. F. Chu (1968), On Estimating the Industry Production Function, *American Economic Review*, 58, 826-839.

ARMSTRONG, M., Cowan, S. and Vickers, J. (1994), *Regulatory Reform: Economic Analysis and British Experience*, Cambridge-MA: MIT Press.

AVERCH, H. and Johnson, L.L. (1962), Behaviour of the Firm under Regulatory Constraint, *American Economic Review, 52*, 1052-1069.

BANKER, R. D. 1984, "Estimating Most Productive Scale Size using Data Envelopment Analysis", *European Journal of Operational Research, 17:* 35-44.

BANKER, R. D. (1993), Maximum Likelihood, Consistency and Data Envelopment Analysis: a Statistical Foundation, *Management Science*, 39, 1265-1273.

BANKER, R. D., Charnes, A. and Cooper, W. W. 1984, "Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis", *Management Science*, 30: 1078-1092.

BANKER, R. D., Conrad, R. F. and Strauss, R. P. 1986, "A Comparative Application of Data Envelopment Analysis and Translog Methods: an Illustrative Study of Hospital Production", *Management Science*, 32: 30-44.

BARON, D. P. 1989, Design of Regulatory Mechanisms and Institutions, In R. Schmalensee and R.D. Willig (eds.), *Handbook of Industrial Organization*, Amsterdam:North-Holland, 1347-1447.

BAUMOL, W. J. and Sidak, J. G. (1994), *Toward Competition in Local Telephony*, Cambridge-MA: MIT Press.

BEESLEY, M. E. and Littlechild, S. C. (1989), The Regulation of Privatized Monopolies in the United Kingdom, *RAND Journal of Economics, 20*, 454-472.

BENEDICT, T. M., Polinsky, J. and Smith, R. J. (1996), Application of the Southern New England Telephone Company for Financial Review and Proposed Framework for Alternative Regulation , Department of Public Utility Control-State of Connecticut.

BLACKMON, G. (1994), *Incentive Regulation and the Regulation of Incentives*, Boston: Kluwer Academic Publishers.

BOUSSOFIANE, A., Thanassoulis, E. and Dyson, R. (1991), Applied Data Envelopment Analysis, *European Journal of Operational Research, 15*, 1-15.

CHANG, Y. and Sueyoshi, T. (1991), An Interactive Application of Data Envelopment Analysis in Microcomputers, *Computer Science in Economics and Management, 4*, 51-64.

CHARNES, A., Cooper, W.W. and Rhodes, E. (1978), Measuring the Efficiency of Decision Making Units, *European Journal of Operations Research, 9*, 181-185.

CHARNES, A., Cooper, W. W., Lewin, A. and Seiford, L. M. (1994), *Data Envelopment Analysis*, Boston: Kluwer Academic Publishers.

DAVIS, V. (1995a), Breaking Away from Franchises and Rate Cases: a Perspective on the Evolution of State Telecommunications Policy, NRRI, mimeo.

DAVIS, V. (1995b), State Telecommunications Reform on the Eve of Amendments to the Communications Act, NRRI, mimeo.

DAVIS, V., Zearfoss, N. and Reed, C. E. (1995), Aspects of Telecommunications Reform: a Results of a Survey of State Regulatory Commissions, NRRI, mimeo.

DUSANSKY, R. and Wilson, P. W. (1994), Technical Efficiency in the Decentralized Care of the Developmentally Disabled, *Review of Economics and Statistics, 76*, 340-345.

FARRELL, M. J. (1957), The Measurement of Productive Efficiency, *Journal of the Royal Statistical Society*, Series A, 120, 253-281.

Federal Communications Commission-FCC (1989), In the Matter of Policy and Rules Concerning Rates for Dominant Carriers, Docket No. 87-313, Report and Order and Second Further Notice of Proposed Rulemaking.

____________. (1990), In the Matter of Policy and Rules Concerning Rates for Dominant Carriers, Docket No. 87-313, Second Report and Order.

____________. *Monitoring Report* (several issues)

____________. *Statistics of Communication Common Carriers*, Washington D.C.: Federal Communications Commission (several issues).

FRANTZ, R. S. (1988), *X-efficiency: Theory, Evidence and Applications*, Boston: Kluwer Academic Publishers.

FRANTZ, R. S. (1992), X-efficiency and Allocative Efficiency: What have we Learned?, *American Economic Review, 82*, 434-438.

HARRIS, R. (1995), Competition and Public Policies in Telecommunications: a Survey of U.S. Developments, *Discussion Paper No. 61*, Economic Research Institute - Economic Planning Agency, Japan.

HOLLENSTEIN, H. (1996), A Composite Indicator of a Firm's Innovativeness. An Empirical Analysis based on Survey Data for Swiss Manufacturing, *Research Policy*, 25, 633-645.

ISAAC, R. M. (1991), Price-Cap Regulation: a Case Study of Some Pitfalls of Implementation, *Journal of Regulatory Economics, 3*, 193-210.

KAISER, H. F. (1974), An Index of Factorial Simplicity, *Psycometrica, 39*, 31-36.

LAFFONT, J. J. and Tirole, J. (1993), *A Theory of Incentives in Procurement and Regulation*, Cambridge-MA: MIT Press.

LEIBENSTEIN, H. (1966), Allocative Efficiency vs. 'X-efficiency', *American Economic Review, 56*, 392-415.

LEIBENSTEIN, H. and Maital, S. (1992), Empirical Estimation and Partioning of X-inefficiency: a Data-Envelopment Approach, *American Economic Review, 82*, 428-433.

LISTON, C. (1993), Price-Cap versus Rate-of-Return Regulation, *Journal of Regulatory Economics, 5*, 25-48.

LOUBE, R. (1994), Price Cap Regulation: Problems and Solutions, Public Service Commission of the District of Columbia, mimeo.

MADDALA, G. S. (1983), *Limited-Dependent and Qualitative Variables in Econometrics*, Cambridge: Cambridge University Press.

MAJUMDAR, S. K. (1995), X-Efficiency in Emerging Competitive Markets: the Case of U.S. Telecommunications, *Journal of Economic Behavior and Organization, 26*, 129-144.

MATHIOS, A. D. and Rogers, R. P. (1989), The Impact of Alternative Forms of State Regulation of AT&T on Direct-Dial, Long Distance Telephone Rates, *RAND Journal of Economics, 20*, 437-453.

MAYER, C. and Vickers, J. (1996), Profit-Sharing Regulation: an Economic Appraisal, *Fiscal Studies, 17*, 1-18.

MITCHELL, B. M. and Vogelsang, I. (1991), *Telecommunications Pricing: Theory and Practice*, Cambridge:Cambridge University Press.

MORRISON, D. (1990), *Multivariate Statistical Methods*, New York: McGraw-Hill, 2nd. ed.

NARUC (1994), *NARUC Report on the Status of Competition in Intrastate Telecommunications*, Washington D. C.: NARUC.

POLLIT, M. G. (1996), Ownership and Efficiency in Nuclear Power Production, *Oxford Economic Papers, 48*, 342-360.

RESENDE, M. (1997), *Regulatory Regimes and Efficiency in U.S. Local Telephony*, unpublished D.Phil. dissertation, University of Oxford.

ROBINSON, P. M. (1982), On the Asymptotic Properties of Models Containing Limited Dependent Variables, *Econometrica, 50*, 27-41.

SAWKINS, J. W. and Accam, B. (1994), Comparative Efficiency Measurement in the Scottish Water Industry: an Application of Data Envelopment Analysis, *Discussion Paper No. 94-12*, University of Aberdeen.

SEIFORD, L. M. (1994), A DEA Bibliography (1978-1992), In A. Charnes, W. W. Cooper, A. Y. Lewin and L. M. Seiford (eds.), *Data Envelopment Analysis: Theory, Methodology and Application*, Boston: Kluwer Academic Publishers.

SEIFORD, L. M. and Thrall, R. M. (1990), Recent Developments in DEA: the Mathematical Programming Approach to Frontier Analysis, *Journal of Econometrics, 46*, 7-38.

SHIN, R. T. and Yin, J. S. (1992), Unnatural Monopolies in Local Telephone, *RAND Journal of Economics*, 23, 171-183.

VICKERS, J. and Yarrow, G. (1988), *Privatization: an Economic Analysis*, Cambridge:MIT Press.

YING, J. S. and R. T. Shin (1993), Costly Gains in Breaking Up: LECs and the Baby Bells, *Review of Economics and Statistics*, 75, 357-361.

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