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REGULATION AND PRODUCTIVE EFFICIENCY: EVIDENCE FROM THE U.S. TELECOMMUNICATIONS INDUSTRY

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Abstract

This paper investigates the impact of incentive regulation schemes on the efficiency of local operating companies in the U.S. telecommunications industry. Efficiency is measured for the period 1988 to 1993 and it is found that the introduction of pure price cap schemes has a strong and positive, but lagged, impact on the technical efficiency of local exchange carriers. Where price cap schemes operate in conjunction with an earnings sharing scheme, there is a positive and more immediate impact on technical efficiency, but the impact is not as strong when compared to the impact of a pure incentive regulation scheme alone. Where only an earnings sharing scheme is in operation, its impact over time is found to be detrimental to technical efficiency, and weaker though broadly positive results are obtained with respect to the impact of incentive regulation on scale efficiency of U.S. local exchange carriers.

1. INTRODUCTION

In the U.S telecommunications industry, a significant aspect of policy which influences the performance of firms, providing both local and long-distance services, is the nature of price regulation in place. For decades the mode of price regulation has been rate-of-return based, or cost-plus in nature,[1] and ever since the seminal analysis by Averch and Johnson (1962),[2] such a regulatory scheme has come under continuing criticism at the hands of policy-makers and academics (Kahn, 1988). Nevertheless, rate-of-return based regulation still continues to be the common practice in many state-level regulatory jurisdictions.

In many other state-level regulatory jurisdictions, however, a major policy switch that has taken place is the introduction of incentive regulation. For many local exchange companies in the U.S. telecommunications industry,[3] the regulatory regime now facing them is one where there is a cap on prices and an explicit objective behind this policy switch, the introduction of incentive regulation, has been to bring about improvements in productive efficiency (Braeutigam and Panzar, 1993; Federal Communications Commission [FCC], 1992). Given the criticality of the local operating sector to the telecommunications industry as a whole, a question of significance

[1] In rate-of-return regulation in which prices for services are set based on the presumption that firms will be allowed to earn a minimum rate-of-return on capital employed, and if firms do not meet their returns targets they have the wherewithal to file upward rate-revision cases. The implementation of rate-of-return regulation focuses on establishing a reasonable limit on companies' profits, and whether or not the rate-of-return allowed to be earned is "fair" has raised empirically unresolved questions (Stone and Haring, 1987).

[2] Their principal findings werê that rate-of-return regulation induces large productive inefficiencies, pricing competitive outputs below marginal cost and over-investment in plant capacity, and their analytical conclusions were extended and corroborated by Bailey (1973).

[3] Long-distance service providers, such as AT&T, are also subject to incentive regulation.

for policy-makers, as well as researchers, that still awaits empirical scrutiny is: has the policy switch involving the introduction of incentive regulation had an impact on the economic performance of local exchange companies in the U.S. telecommunications industry?[4]

Taking advantage of the natural experiment in public policy that is in progress, as a result of which significant variation has been introduced in the state-level regulatory regimes that local operating companies face, this study assesses the impact of the introduction of incentive regulation on the performance of firms in the U.S. telecommunications industry. Measuring performance as productive efficiency, evidence on the role that price cap schemes play in explaining variations in efficiency among local exchange companies is generated[5] and the paper

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[4] Policy switches are one-off, often irreversible, changes in aspects of policy that govern a key facet of economic activity as a result of which the behavior of economic actors changes leading to changes in the performance of firms. Changes in policies and environmental conditions create challenge for firms as different sets of circumstances begin to affect their activities. However, hysteresis effects (Dixit, 1991) may be present and unless changes in the institutional environment of firms are brought about by strong policy switches, the behavior of firms may not *change at all (Flood, 1992). Dixit (1991) summarizes an existing literature and provides an analysis of why hysteresis effects may persist. Because behavior is not easily reversed, because the environment has ongoing uncertainty, and because information arrives gradually, there may be a value to waiting to be induced to change behavior. Dixit (1991: 109) also classifies such patterns of behavior as "a benevolent tyranny of the status-quo." Because of the environmental changes taking place hysteresis effects may disappear, and one key area of economic performance where the impact of a strong policy switch may make itself felt is in productive efficiency. Conversely, the policy switch may not be strong enough to make an impact on economic performance. The literature on policy switching has developed in attempts to explain economic behavior during periods of monetary crises. Flood (1992) describes it as an approach designed to help investigators studying both micro-economic and macro-economic data come to grips with the "peculiar" behavior that surrounds crises or other discrete events.

[5] Local exchange companies provide the primary infrastructural backbone for land-based telecommunications in the United States. The analysis is, therefore, of practical significance since the results will reveal whether the fundamental policy switch involving the introduction of incentive regulation schemes has had an impact on the performance of firms in that segment of the telecommunications backbone in the U.S. made up by the local exchange companies.

unfolds as follows: in section 2 the characteristics of incentive regulation schemes are discussed, section 3 contains details of the empirical analysis carried out, section 4 is a discussion of the results obtained, and section 5 concludes the paper.

2. INCENTIVE REGULATION IN THEORY AND PRACTICE

2.1 The Issue

The sources of misgivings with rate-of-return regulation arise for several reasons. First, x-inefficiencies are perpetrated. It is intuitive that if a firm is allowed to charge a price that will cover all its costs, the firm has either little incentive to reduce costs, or look for innovative ways of reducing such costs. The firm does not, in any way, suffer from being x-inefficient, and x-inefficiencies are passed on to customers. The Averch-Johnson [A-J] analysis has, in addition, shown that if a firm is allowed to earn a rate-of-return in excess of its cost of capital, it will have an incentive to use too much capital and too little of other inputs. The outcome is higher costs per unit than if the most efficient combination of inputs were to be used.[6]

A second source of disquiet arises with respect to what goes into the cost base. Rate-of-return regulation assumes that costs are known when prices are set. This requires that the regulator expend effort in becoming knowledgeable about the composition of the firm's true cost structures, so that the appropriate rate base can be used in the determination of prices. In the determination of the cost structures and the rate base, the regulator has also to possess information and knowledge about allocation of costs between federal and state jurisdictions, and between non-competitive and competitive services, so that firms do not misreport costs between

[6] Though the assumptions of the A-J model have been questioned (Joskow, 1973), a number of empirical studies (Courville, 1974; Hayashi and Trapani, 1976; Peterson, 1975; Spann, 1974), set primarily in the context of the electric utility industry, have established the A-J effect to hold.

segments. These factors place large administrative burdens on regulatory authorities.

2.2 Characteristics of Incentive Regulation Schemes

Incentive regulation schemes, referred to as price cap schemes are policy innovations which attempt to resolve many of the problems associated with a rate-of-return regulation scheme, and were introduced in the United Kingdom to regulate British Telecom following the Littlechild (1983) report.[7] Price caps represent a contract between a firm and the regulator in which a price ceiling is set for a definite period of time, and subject to that ceiling firms are able to price at whatever levels are feasible.[8] Given set price ceilings, firms are free to retain the surpluses that they earn as a result of attaining cost efficiencies, and are also induced to make the necessary investments that may permit such efficiencies to be gained.[9] Thus, price caps, or price-minus regulatory schemes, help reverse many of the negative or egregious properties of

[7] The popularity of the price-caps idea is a post introduction-in-the-U.K. phenomenon, though in the U.S. Michigan Bell, a local operating company in the mid-West, was regulated by price-caps between 1980 and 1983 (Acton and Vogelsang, 1989).

[8] Apart from the key characteristic, that regulators fix a price ceiling for a period of time during which rates are not adjusted downwards by the regulatory authorities, Acton and Vogelsang (1989) define three additional properties of contemporary price-cap schemes, each owing their origins to earlier literature in the area. Price ceilings are generally set for clearly identified baskets of services so that cross-subsidization between the services in different baskets do not occur (Vogelsang and Finsinger, 1979); price ceilings are adjusted periodically based on a pre-announced adjustment factor (Sudit, 1979); and in longer intervals of several years, adjustment factors, baskets and weighting schemes are reviewed and changed if necessary (Baumol, 1968).

[9] Analytical results proving that price-cap regimes induce investments in cost-reduction technologies have been provided by Cabral and Riordan (1989). There is now a large literature on price-cap schemes. See, for example, Barnich (1992), Brennan (1989), Kwoka (1993), Laffont and Tirole (1993), Lewis and Sappington (1989), Liston (1993), Mitchell and Vogelsang (1991), Neu (1993), Sappington (1994), Schmalensee (1989), Sibley (1989) and Weisman (1994).

rate-of-return, or cost-plus, regulation.[10]

Beesley and Littlechild (1989), while noting that rate-of-return and price cap schemes both address the necessity of securing an adequate return for a firm's shareholders, highlight the sources of differences between the two schemes which lead price cap schemes to be superior in inducing efficiencies. First, there is an externally-determined period, by the regulatory authority, between price reviews. Thus, there is a fixed period for firms operating strategies and enjoy the benefits of reduced costs. Second, price cap regulation schemes do not use ex-post cost data in setting prices; rather, ex-ante productivity and demand forecasts are used in price setting. Interactively, these two factors taken together mean that firms are not deterred from making efficiency improvements either by fear of confiscation within the defined period that the scheme is in operation, or that future prices are an extrapolation of past costs. Third, price cap regulation does not require a large administrative apparatus to help determine firms' costs structures.

2.3 Applications of Incentive Regulation Schemes

The first major application of a price cap scheme was in the U.K., where it has been claimed to be effective in promoting efficiency on the part of British Telecom (Beesley and Littlechild, 1989; Neri and Barnard, 1994). The U.K. method of incentive regulation, titled RPI-X, has also been applied to regulate other segments of the public utilities sector which have been privatized (Vickers and Yarrow, 1988). In the U.S. telecommunications industry a two-tiered regulatory system exists; one at the federal level where the regulator is the FCC, and the other at the level of public utility commissions in the various states and the District of Columbia. Price

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[10] Indeed, as Brauetigam and Panzar (1989: 193) have pointed out: "Much of the original excitement about PC's stemmed from the hope that a contract specifying PC's would induce the regulated firm to minimize its production costs and pursue economically efficient innovation."

cap plans began to be developed in the late 1980s (FCC, 1987) and since 1991 AT&T's service offerings with respect to inter-state long-distance calls have been regulated by the FCC under a FCC price cap scheme, while many state-level regulatory bodies have, in many cases earlier than FCC, introduced incentive regulation in respect of the intra-state and inter-LATA services that AT&T provides.

In the United States local operating companies are an important constituent of the industry;[11] and since 1987 when the state of Nebraska introduced price cap regulation, along with deregulating the telecommunications industry almost fully in the state, a number of state utility commissions have introduced various forms of incentive regulation for local exchange carriers, at differing points in time after 1987. As a result, there is both cross-sectional variation between states in the nature of regulatory regimes which influence local operating companies, as well as time-series variation as the regulatory regime evolves within a particular state.

A principal difference between federal and local level incentive regulation is that at the local level rate-of-return constraints continue to operate in conjunction with price cap schemes (Braeutigam and Panzar, 1993). In a pure price cap plan, the actual earnings of the firm do not affect future prices; with a price cap plan coupled with an earnings sharing scheme, provisions exist for adjusting prices if the firm's earnings fall outside a certain range. There is no generic sharing plan, per-se, but a common form of an earnings sharing plan is one where the local telephone company is allowed to retain all earnings allowing a specified level of return, retain

[11] Local operating companies provide double the level of telecommunications services as compared to the volume of services provided by the long-distance carriers in the U.S. Local operating companies provide not only local (residential and business) telephone services but also intra-LATA toll services, which as a separate category of service accounts for approximately a third of all calls provided by a local operating company.

half of all subsequent additional earnings permitting the company to earn, say, an additional percentage rate-of-return, and has to refund earnings above that level to ratepayers (Braeutigam and Panzar, 1993). In addition, a number of states have implemented incentive regulation schemes where there is only an earnings sharing scheme but no price cap plan in effect. This type of a regulatory regime is, therefore, similar in its impact to a standard rate-of-return based regime.[12]

2.4 Evidence as to the Impact of Incentive Regulation

Two contemporary studies have empirically examined the impact of incentive regulation. Using data for 1983 and 1987, and a dummy variable to capture the existence of price cap regulation, Mathios and Rogers (1989) examine cross-sectional variation in the way different states regulate AT&T's long-distance rates and find that incentive regulation does lead to lower long-distance prices. Greenstein, McMaster and Spiller (1994) use data for the period 1986 to 1991 and examine the effect of cross-sectional and time-series variation in state-level incentive regulation on telecommunications firms' investment decisions. They find that price cap schemes do influence the level of deployment of cost-reducing technologies by local exchange companies. Therefore, the evidence that has emerged so far as to the impact of incentive regulation shows that the resulting behavior of firms is consistent with theory. However, no studies as yet have examined whether the introduction of incentive regulation schemes has impacted productive efficiency.

[12] A recent detailed documentation of local level regulatory environments (Greenstein, McMaster and Spiller, 1994) finds that 22 states have implemented price-cap schemes, of which 8 operate pure price-cap schemes and 14 operate some form of an earnings sharing mechanism in conjunction with a price-cap scheme. In addition, 14 states operate an earnings sharing scheme exclusive of a price-cap component. In all other states, rate-of-return based regulation exists.

3. EMPIRICAL ANALYSIS

3.1 Approach and Empirical Model

To evaluate the effect on productive efficiency of a change from rate-of-return to incentive regulation, this study uses firm-level data for a balanced panel of 45 local operating companies obtained from the Statistics of Communications Common Carriers, collated by the FCC, based on periodic reports submitted by the companies and published annually, for the years 1988 to 1993. The companies evaluated account for 99 percent of all installed telephone lines in the United States, with the data for these companies being contemporary and containing detailed information with respect to several firm-specific factors. The time-period, 1988 to 1993, is also one during which the introduction of state-level incentive regulation schemes commenced, and in that period a number of states moved from rate-of-return to incentive regulation. Such policy switches have taken place at various points during the six-year period, and there is both cross-sectional as well as time-wise variation in respect of the regulatory regimes that local operating companies face.[13]

Prior research (Majumdar, 1995) used similar but older FCC data and analysis procedures to evaluate efficiency, and a similar approach is followed in the present study with, first, the relative productive efficiency of firms being determined using data envelopment analysis (DEA), a procedure useful for disaggregated firm-level analysis. Thereafter, two types of output generated by the DEA algorithms, respectively capturing the technical and scale efficiency of firms, are

[13] As Braeutigam and Panzar (1993: 197) have remarked: "The "PC Revolution" will stimulate the profession to engage in more applied research: positive analyses which attempt to assess the effects of the mix of plans in effect." Therefore, with the present data, control conditions for assessing the impact of the natural experiment that is underway, with a mix of plans in place across the country, are ideal.

used as the dependent variables in a model where the key explanatory variables capture the differences in regulatory regimes each operating company faces. A set of variables which are potential explanators of variations in efficiency patterns are included as controls. This particular, micro-level approach also helps to avoid an aggregation problem characterizing studies of the telecommunications industry (Davis and Rhodes, 1990; Waverman, 1989).

The model estimated is:

$$PRODUCTIVE\ EFFICIENCY_{it} = \beta_0 + \beta_1\ PRICE\ CAP_{it} + \beta_2\ SHARING\ \&\ CAP_{it} + \beta_3\ SHARING_{it} + \beta_4\ FIBER_{it} + \beta_5\ SEPARATION_{it} + \beta_6\ TOLL\ CALL_{it} + \beta_7\ BUSINESS\ LINES_{it} + \beta_8\ SWITCH\ SHARE_{it} + \beta_9\ SIZE_{it} + \beta_{10}\ OWNERSHIP_{it} + \beta_{11}\ COMPENSATION_{it} + \beta_{12}\ CORPORATE\ COSTS_{it} + \varepsilon_{it} \quad (1).$$

A description of the variables used in the model is given in Table 1.

3.2 Estimating Productive Efficiency

The log of the productive efficiency measures, estimated for each of the 45 local operating companies for each of the years 1988 to 1993 using DEA, are the dependent variables in the model. Charnes, Cooper and Rhodes (1978) [CCR] develop and Banker, Charnes and Cooper (1984) [BCC] extend an efficiency measure first developed by Farrell (1957) using a fractional program where the ratio of the weighted outputs to weighted inputs of each observation in the data-set is maximized. For each observation a single statistic, ranging between 0 and 1, which is a measure of how efficient each observation is in converting a set of multiple inputs jointly and simultaneously into a set of multiple outputs, is calculated. Using only observed output and input data, and without making any assumptions as to the nature of underlying technology or functional form, the algorithm calculates an ex-post measure of the efficiency of each observation, accomplished by constructing an empirically-based frontier, and by evaluating each observation against all others included in the data set.[14]

3.2.1 Analytical Details of DEA

The generalized DEA model is presented by the following formulation:

$$\text{Max } e_{0,0} \tag{2}$$

subject to: $e_{j,0} \leq 1$, $\forall j$; $\mu_{r0} \geq \in$, $\forall r$; and $\nu_{i0} \geq \in$, $\forall i$; where $j > 1,....n$ is the index for observations, 0 being used as the index for the observation being specifically evaluated and $e_{0,0}$ is the efficiency score for that observation, $r = 1,....R$ is the index for the outputs ($y_{rj} \geq 0$ is output r of observation j), $i = 1,....I$ is the index for the inputs ($x_{ij} \geq 0$ is input i of observation j), $e_{j,0}$ is the relative efficiency of observation j when observation 0 is evaluated, μ_{r0}, ν_{i0} are the output and input weights, respectively, associated with the evaluation of observation 0, and $\in$ is a non-Archimedean infinitesimal quantity. In (1), the input (x_{ij}) and output (y_{rj}) factors are known quantities observed from the activities of the observations and the factor weights (μ_{r0} and ν_{i0}) are the decision variables. Defining,

$$e_{j,0} = \sum_{r=1}^{R} \mu_{r0} \cdot y_{rj} \,/\, \sum_{i=1}^{I} \nu_{i0} \cdot x_{ij} \tag{3}$$

yields the CCR model, which is the basic DEA model.

[14] Each observation rated as efficient is used to define an efficiency frontier, and firms not so rated are evaluated by comparison with a firm on the frontier, with broadly similar output or input mixes as the firm being compared. Thus, data from efficient firms are used to create a frontier based on the principle of envelopment. The efficiency measure gives an indication of how well each firm performs relative to its potential and to other firms. The best firms score 1, on a scale of 0 to 1, and for the inefficient firms the difference in score gives an idea of the efficiency improvement that is possible.

3.2.2 Treatment of Scale Effects Within DEA

Linear-programming based approaches (Dorfman, Samuelson and Solow, 1958) used in empirically evaluating economic phenomena have been hampered by a constant returns to scale constraint, a condition useful for theoretical purposes but not of practical use (Hicks, 1989). The original Farrell and the CCR models also incorporate this constraint, and it is not possible to know whether efficiency arises for scale or other reasons. Banker, Charnes and Cooper (1984) show that the efficiency score generated by the CCR model is a composite total efficiency score which can be broken up, using the BCC algorithm, into two components: one capturing scale efficiency, which is the ability of each observation to operate as close to its most productive scale size as possible,[15] and the other capturing pure technical or resource-conversion efficiency.

To isolate pure technical efficiency, the BCC algorithm assumes that variable returns to scale exist for firms, and a variable u_0 is added in the programming formulation so that the

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[15] Within an industry firms of different sizes can exist because each firm operates at a different scale of output generation (Silberston, 1972). Due to reasons relating to, say, the financial, marketing and risk-bearing capabilities of firms, there may be no one optimal size, dictated by technological considerations, or a master production function for the industry as a whole; each firm, however, may have a most productive scale size for its given capability sets and operating production function (Robinson, 1932). The concept of scale efficiency measures the extent to which firms deviate from their most productive scale size, the point on the cost curve where constant returns to scale exist (Gold, 1981), though firms may be either enjoying increasing returns or suffering from decreasing returns while being scale inefficient. Scale inefficiency is a measure of the divergence between present scale of operations and the most productive scale size attainable by individual firms. Changes in patterns of scale efficiency can arise for several reasons. Firm-level factors may influence scale efficiency, and one such factor can be technical change. With increasing modularity of switches, firms may rapidly scale up or scale down in order to meet demand fluctuations (Huber, 1989; Shepherd, 1983), and can enjoy greater scale efficiencies because of abilities to make rapid adjustments to most productive scale. However, there can be lags in the speed of adjustment. Simultaneously, exogenous factors, such as policy regime changes, may provide significant pressures on firms to become scale efficient, since a basic firm-level objective is cost minimization.

hyperplanes for each observation do not pass through the origin, unlike in the CCR model, where hyperplanes pass through the origin because constant returns to scale are assumed. In the constraint set for the linear programming model, this variable is kept unconstrained so that it can take on values, depending on the data, which are negative (denoting increasing returns to scale may exist), 0 (denoting constant returns to scale may exist) or positive (denoting decreasing returns to scale may exist) for each j^{th} observation. Therefore, defining the relative efficiency measure as,

$$e_{j,0} = \sum_{r=1}^{R} \mu_{r0} \cdot y_{r_j} - u_0 \;/\; \sum_{i=1}^{I} \nu_{i0} \cdot x_{ij} \tag{4}$$

where u_0 is the unconstrained decision variable yields the BCC model. The CCR model generates a total efficiency score, while the BCC model generates a technical efficiency score. Dividing the CCR score by the BCC score generates a measure of scale efficiency for each observation.[16]

3.2.3 DEA Models Estimated

Within the DEA framework two estimation approaches are feasible. First, it may be assumed that firms conserve inputs; then, the algorithm evaluates minimal use of inputs, with outputs generated kept constant. Second, it may be assumed that each firm augments outputs; given a finite stock of inputs available, firms seek to maximize outputs that can be generated with

[16] The advantage of DEA also lies in its approach. DEA optimizes for each observation, in place of the overall aggregation and single optimization performed in statistical regressions. Instead of trying to fit a regression plane through the center of the data, DEA floats a piece-wise linear surface to rest on top of observations. This is empirically-driven by the data, rather than by assumptions as to technology or functional forms. The only assumptions made are that of piece-wise linearity and convexity of the envelopment surface, and the DEA algorithms also take each observation's idiosyncrasies into account in the computation of relative efficiency score, unlike in regression-based estimation techniques where efficiency parameters are calculated based on an averaging process (Seiford and Thrall, 1990).

these. For the 45 local operating companies, for the years 1988 to 1993, the BCC and CCR input-conserving algorithms are used to calculate efficiency scores, which are the dependent variables in the models estimated, and the BCC technical efficiency and scale efficiency scores are computed for each observation. Three outputs (local calls, inter-LATA toll calls, and intra-LATA toll calls) and three inputs (number of switches, number of lines, and number of employees) are used in the computations. The choice of these variables is consistent both with telecommunications industry technical literature (Green, 1992; Skoog, 1980) and prior research (Majumdar, 1995).

3.3 Explaining Variations in Technical Efficiency

3.3.1 Accounting for Regulatory Effects

While a number of aggregate state-level classifications of regulatory regimes in the U.S. exist, the Greenstein, McMaster and Spiller (1994) documentation of the regulatory conditions faced by each individual firm is used for the current analysis. Within a state two operating companies need not face the same set of institutional rules; for example, in Michigan different regulatory schemes may exist for GTE Midwest and Michigan Bell. Hence, the information, as documented, on firm-specific regulatory regimes is useful in marrying with the firm-specific FCC information available. Thereby, the specific effects of incentive regulation regimes faced by firms on productive efficiency can be isolated. *PRICE CAP* is a variable taking on the value of 1 if the state in which a firm operates has implemented pure price cap regulation in the various years that are studied, and 0 otherwise. Between 1987 and 1993, many states -- for example, Kansas, Maine, Nebraska and Wisconsin -- have implemented such a regulatory scheme.

There are several multi-state operating companies in the U.S., e.g. GTE Northwest. For such companies a *PRICE CAP* index is constructed. Each state in which such a company operates can be identified as one which has either implemented or not implemented a pure price cap scheme during the years studied. An index of exposure to pure price cap regulation is derived by weighting positive state dummies by the proportion of lines that each state contributes to the total telephone lines operated by the operating company. Data on the number of lines operated by each company are available from a periodic FCC Monitoring Report (1993), and are the most direct measure of the extent of each operating company's activities in any particular state.

Price cap schemes can also have a price-freeze component, as a result of which the abilities of companies to price flexibly reduce (Greenstein, McMaster and Spiller, 1994). Under a price freeze companies cannot necessarily reduce prices, but they do face a price ceiling as they would anyway when faced with a flexible pricing regime. Since a price cap regime induces behavioral changes in firms as a result of the price ceiling enforced, and is a price-minus regime in practical terms, the behavioral consequences of frozen versus flexible prices in a price cap regime are likely to be similar with respect to inducing operational efficiencies.

A number of states operate an earnings sharing system in consonance with a price cap regime. For example, to regulate Chesapeake and Potomac Telephone Company (C&P), which is the monopoly service provider in the District of Columbia, since January 1993 a price cap scheme has been adopted in consonance with an earnings sharing scheme where C&P retains all earnings between 11.5 and 13.5 percent, but splits half of all excess earnings yielding a return greater than 13.5 percent with rate-payers (Greenstein, McMaster and Spiller, 1994). Some of the other states where similar schemes are in operation are California, Florida, New York and Texas.

Whether a pure price cap scheme is better than one which combines an earnings sharing component is an empirical issue, but theory suggests that a pure price cap scheme will have superior efficiency properties. For single-state operating companies a dummy variable, coded 1, is used to denote the existence of a price cap scheme which is coupled with an earnings sharing component for the years studied and 0 otherwise. For multi-state operating companies the *CAP & SHARING* index is constructed in a manner similar to constructing the *PRICE CAP* index.

While a pure earnings sharing scheme is conceptually similar to rate-of-return based regulation in its efficiency properties, a number of states have implemented such schemes as an alternative to either rate-of-return or any other form of incentive regulation. Where such is the case in any state, the coding pattern and index-creation procedures followed for creating the variable *SHARING* are the same that have been followed for creating *PRICE CAP* and *CAP & SHARING*. However, the period studied extends between 1988 and 1993, and during this time-frame some states have moved from one form of incentive regulation to another. For example, the state of Wisconsin operated an earnings sharing scheme for Wisconsin Bell between 1987 and 1989, but moved over in 1991 to a form of pure price cap regulation (Greenstein, McMaster and Spiller, 1994). Thus, the way the regulatory variables are constructed captures the changes taking place over time in state-level institutional environments.

3.3.2 Controlling for Technical Change

The DEA algorithm makes no assumption as to the underlying technology used by firms in its estimation of comparative firm-level efficiency. Nevertheless, controlling for the effects of rapid technical changes taking place in the telecommunications sector is crucial in any study of efficiency, and though earlier studies have found positive results they have been criticized for the use of ad-hoc or aggregate measures, such as simple time-trends, or annual R&D expenditures by the Bell organization, to capture technical change (Waverman, 1989).

From 1988 onwards, the FCC data permit the use of finer measures of firm-level technical change, such as the extent of fiber optic diffusion or the level of line digitization, both of which are relevant measures of technical progress in the contemporary industry context (Egan, 1991). However, in 1991 the plant data reporting format was changed, and digitization data were re-classified. Therefore, digitization data for the years 1988 to 1990 are not comparable with data for the years 1991 onwards, creating a problem for the present analysis. Conversely, fiber optic data are comparable for all years, and the variable *FIBER* which is a relative measure of the diffusion of fiber optic technology into the total network[17] is introduced in the model, helping to control for the impact of technical change on firm-level efficiency.[18]

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[17] Since 1986 the total deployment of fiber optics in aggregate has also risen sharply, from 882,000 route-miles to 6,331,000 route-miles by 1993. The actual route-miles deployment figures, on a year-to-year basis, are as follows:- 1986, 882,000; 1987, 1,206,000; 1988, 1,783,000; 1989, 2,297,000; 1990, 3,249,000; 1991, 4,389,000; 1992, 4,389,000; and 1993, 6,331,000 (Kraushaar, 1994). These numbers indicate increasing diffusion of new technology that can considerably enhance the operating efficiency of a telecommunications network.

[18] Fiber optics technology uses a cable made of silicon to transmit voice and data, using lightwave as the transmission medium. While the idea of using lightwave as a communications medium has existed for over a century, and though silicon is the most abundant material on earth, two recent technological developments have made the manufacture and usage of fiber optics practical. First, there has been the development of laser. Second, there has been the development of glass fiber of a high purity, permitting the manufacture of cables in which only a very small portion of a light signal emitted is lost. When a laser source is triggered on and off at high speed, the 0s and 1s of a digital communication channel are transmitted to a detector, usually a diode. This detector then converts the received signal pulses from light back to electronic pulses and couples them to multiplexing equipment, which then combine multiple signals into a single channel (Green, 1992). A key advantage of fiber optic cable over the traditional copper twisted-pair cable is the amount of bandwidth capacity made available. It is conservatively estimated that a fiber optic cable can carry 16,000 phone calls at once compared to the 24 calls that copper wire can handle. However, apart from voice and data handling advantages, there are other primary technical benefits associated with fiber optics. First, longer transmission distances are possible. This reduces the need for repeaters in the transmission system. Second, installation is

3.3.3 Controlling for Institutional and Business Environment Effects

Another major institutional aspect in the telecommunications industry is the way investments and costs of local operating companies are assigned to the inter-state market, so that costs may be collected from the long-distance carriers via the separation and settlements process. Division of local operating company investments in plant between the federally-regulated inter-state long-distance activity and state-regulated intra-LATA long-distance and local calling activities has to take place so that all services bear cost burdens, and without the local company plant in place no inter-state telephone calls can be delivered to customers. However, plant and cost division is difficult, because of the inherent difficulty in separating plant and costs which are common and incurred on an overall basis for activities associated with operating the network, and such a division is often based on non-economic political criteria (Bolter, 1984).

Local operating companies will have incentives to ensure that their investment and associated costs are allocated to the inter-state jurisdiction, so that a greater proportion of their total operating costs are borne by other carriers. If a lower proportion is so borne, then local companies have to bear the costs, a lot of which cannot be recovered by way of prices charged to customers because local rates are stringently regulated. A variable, *SEPARATION*, is constructed using data obtained from the FCC Monitoring Report. The report identifies for each local operating company their total plant investment and the amounts of these allocated to state

considerably easier as the weight differential is significant. An equal amount by weight of fiber optic cable, compared with an equal amount by weight of copper cable, is three times as long and has over 100 times the capacity. Third, in the presence of high humidity copper tends to corrode, and replacement of wire is frequently necessary, so as to stop signal degradation. Fiber optic cables last longer, and also enhance transmission quality by suppressing electrical noise, since glass cannot conduct electricity (West, 1986).

and federal jurisdictions. *SEPARATION* is measured as the relative proportion of total investments allocated to the state jurisdiction, and the larger this proportion the stronger the incentives are for local operating companies to be efficient; thus the coefficient is expected to be positive.

The business environment of local operating companies has changed in the late 1980s and the 1990s and for companies with different mixes of business there can be differential impacts on performance. There is competition in both toll and local calls markets, in varying degrees. In inter-LATA toll markets competition is intense; however, local operating companies, though demanding the right of entry, are not yet permitted entry. In intra-LATA markets, where local companies have had a monopoly, competition is slightly less intense, though a number of major states permit competition, and the number of states opening up this market to other entrants is increasing every year. Intra-LATA toll calls account for almost a third of all calls accounted for by a local company. The variable *TOLL CALL*, which is the percent of toll relative to total calls, helps capture the exposure of companies in toll markets.

In the local calls segment the threat of bypass, a direct connection between a customer's premises and another carrier or a self-contained system avoiding the operating company's system fully (Bolter, 1984), is significant and may induce efficiencies, since revenues are lost through bypass but all costs still have to be incurred to maintain the network in its present existing size and condition. Business customers are important for revenue-raising purposes and are also the customers most likely to bypass the local network (Bolter, McConnaughey and Kelsey, 1990). *BUSINESS LINES*, which is the percentage of a firms's lines that are business lines, measures the susceptibility of bypass and can positively impact efficiency, though there may be negative efficiency implications arising from having to tailor services for idiosyncratic customer needs.

The theory of industrial organization (Scherer and Ross, 1990) suggests that market power and efficiency have an inverse relationship because dominant firms, especially in relatively controlled markets such as telecommunications where territory shares have been awarded by institutional fiat and not obtained through market success, do not perceive the threat of instant displacement by newcomers. Such perceptions tend to breed inefficiencies, because the availability of a number of customers to whom costs can be passed on is taken for granted (Leibenstein, 1976). *SWITCH SHARE*, measured as the percentage of switches a company possesses in its given operating area relative to the total number of switches all firms possess in that operating area, captures relative share of installed base, and its expected impact is negative.

3.3.4 Controlling for Firm-Level Characteristics

The size of firms is a correlate of efficiency, and *SIZE* is introduced as a control variable. Key features of large firms are the diverse capabilities that they possess, coupled with the formalization of procedures. Such attributes make the implementation of operations more effective since several complementary skills can be brought to bear (Penrose, 1959). However, alternative points of view suggest that as firms become larger efficiency diminishes because of loss of control by top managers over strategic and operational activities within the firm (Williamson, 1967). With increasing bureaucratization and increased hierarchical levels, incentives for managers to pursue activities efficiently tend to diminish, since the rents from such activities are more widely shared among a larger body of people who may not all have contributed equally to the firms' activities. Conversely, smaller firms are more flexible and can readily adapt to situations where rapid decision-making with respect to activities is required (Carlsson, 1989).

The U.S. local operating sector consists of a number of firms of widely-varying sizes, and if significant technological economies of scale do exist in the sector, as popularly assumed, then larger firms are likely to enjoy scale efficiencies; these efficiencies may, however, be vitiated by the administrative diseconomies of scale that have been identified to arise in larger organizations. Larger firms in the sector also tend to be multi-state operators, thereby adding another dimension of complexity to their operations and administrative organization. The issue of whether size is positively or negatively correlated with efficiency in the local operating sector is an issue the resolution of which has to be empirical, and will have policy consequences.

Ownership is also a key determinant of efficiency (Leibensten, 1976). Research has established that between 1894 and 1910 in situations where the AT&T-owned local operating companies were able to exploit market power they were relatively inefficient while the presence of competing independent carriers reduced such inefficiencies (Bornholz and Evans, 1983; Gabel, 1994). Research, however, also establishes that the AT&T-owned operating companies, called Baby Bells after 1984, in the post-divestiture period have made radical strategic changes to outstrip the other independent companies in performance (Schlesinger, Dyer, Clough and Landau, 1987). *OWNERSHIP* is constructed as a dummy variable, taking the value of 1 if a Baby Bell company and taking the value 0 otherwise, and for the period studied Baby Bells are expected to be more efficient than the other local operating companies.

Firm-level capability-enhancement decisions can play a positive role in determining relatively superior performance. First, *COMPENSATION,* measured as the average dollar value of compensation paid per employee, helps capture differences in the firm-level quality of human capital, given that human capital quality differences can help explain efficiency differences.

CORPORATE COSTS, defined as the percentage of expenses incurred in activities such as planning and human resource development relative to total operating expenses, helps measure the relative quantum of activities being undertaken which aid in the development of a firm's longer-term business capabilities. Both a relatively higher quality of human capital, and relatively greater spending on corporate development activities are expected to positively impact on performance.

3.4 Regression Estimation Procedures

A pooled model which corrects for cross-sectional heteroscedasticity and time-wise auto-regression is used for estimating the regression model. The specific model used is one recommended by Kmenta (1986), which assumes heteroscedasticity and auto-regression but cross-sectional independence. In general, the policy switching literature assumes that there are no time lags between policy announcements and their impact (Flood, 1992). Nevertheless, this particular assumption may not be tenable with empirical experience, and there can be obvious time lags between the implementation of many institutional changes and their subsequent impact on firms' behavior, especially where the displacement of one long-established regulatory regime, such as the rate-of-return based system, with another regime which is considerably more novel in its approach, is considered. The model is also estimated using unrestricted one-period and two-period lags for the regulatory variables and a one-period lag for the technical change variable.

The choice of the lag length, as applied to assess the impact of the regulatory variables, depends on a number of factors, and the exact lag length has to be eventually empirically-derived from the data of firms' actual experiences. In the present study there is, however, one key constraint which limits the number of lags that can be included, the short length of the time-series. Also, the policy switch being studied is one where events are still taking place, in various states, as at the date of estimation, and the research is quite contemporary. Therefore, the length of time that has passed since occurrence of the actual events is very limited. Assuming that firms are able to make firm-level operating adjustments within a year of the policy switch, the impact of such a policy switch is likely to be felt by the second year; thus, estimating the model with a two-period lag will generate empirical insights as to whether the price cap policy switch has, in the relatively near-term, had the hoped-for impact on firms' behavior and performance.

4. RESULTS

4.1 Impact of Incentive Regulation on Technical Efficiency

The estimation results are given in Tables 2 and 3. Table 2 contains regression results where the dependent variable is the pure technical efficiency score calculated using the BCC input-conserving algorithm. Table 3 contains regression estimates where the dependent variable is the scale efficiency score, which is calculated by dividing the CCR efficiency score by the BCC efficiency score, and, again, an input-conserving algorithm is used for estimating the CCR efficiency scores. Six equation variants are estimated, with different lag structures and including or excluding the control variables to test for robustness of the regulatory variables.

The results that are obtained with respect to the BCC technical efficiency score are discussed first. Equations 1 and 2 in Table 2 are estimated without any lag effects, and in both equations *PRICE CAP* is not significant. Conversely, *SHARING & CAP* is positive and significant at a 95 percent level, while *SHARING* is not significant. Equation 1 excludes the control variables, while equation 2 includes them. In the latter equation, among the control variables, *FIBER*, *SWITCH SHARE* and *CORPORATE COSTS* do not turn out to be significant, while all other control variables are of the expected sign and significance.

Equations 3 and 4 have one-period lags included for the regulatory and technical change variables, and exclude and include the control variables respectively. In these equations, with one-period lags factored through for the regulatory variables, the contemporaneous and lagged values of *PRICE CAP* are not significant, while the lagged value of *SHARING & CAP* is significant. The contemporaneous *SHARING* variable is significant and positive, while the one-period lagged value turns out to be negative and significant. The contemporaneous *FIBER* variable is still not significant, while the one-period lagged *FIBER* variable is positive and significant. In the equation where controls are included, apart from *TOLL CALL* which is now not significant, all other control variables which were found to be significant in equation 2 retain their signs and significance.

In equations 5 and 6 contemporaneous, one-period lagged and two-period lagged regulatory variables and one-period lagged technical change variables are included. In equation 5, no control variables included, only the two-period lagged value of *PRICE CAP* is positive and significant, while in equation 6, all control variables included, contemporaneous and one-period lagged values of *PRICE CAP* are negative and significant, albeit at a 90 percent level, while the two-period lagged *PRICE CAP* variable is positive and significant. The one-period lagged *SHARING & CAP* variable is significant only in equation 6, while the two-period lagged *SHARING & CAP* variable is positive and significant in both equations. The contemporaneous value of *SHARING* is positive and significant, one-period lagged values of *SHARING* are not significant, while the two-period lagged values of *SHARING* are negative and significant. These results hold in equations 5 and 6. Apart from *CORPORATE COSTS*, now positive and significant, all other control variables have the same sign and significance obtained in equation 4.

What do these results imply? The introduction of pure price cap schemes does impact positively and significantly on the technical efficiency of the local operating companies, as expected, but only after a two-period lag. Conversely, perhaps because rate-of-return regulation is so widespread, a combination of price cap and earnings sharing schemes, as captured by the *SHARING & CAP* variable, has both immediate as well as persistent effects on efficiency. A comparison of the magnitudes of the significant *PRICE CAP* and *SHARING & CAP* variables are, however, in order. Such comparison reveals that the magnitude of the *PRICE CAP* variable is greater than that of the *SHARING & CAP* variable. Though it takes longer for the introduction of price cap regulation schemes to make their effects felt, as a result of hysteresis effects which may be present in firm-level behavior, as well as the relative novelty and scarcity of such inventive regulation schemes, ultimately the effect on firms is consistent with the postulates of economic theory, and the policy switch that has taken place in the U.S. telecommunications industry has impacted positively on economic performance, as has been initially measured by technical efficiency.

The results obtained also show that the introduction of pure earnings sharing schemes, as captured by the variable *SHARING*, in the various regulatory jurisdictions, is not conducive to long-run efficiency. While in the immediate aftermath of the introduction of such schemes, efficiency is found to be positively enhanced, as equations 3 to 6 show, the novelty associated with such schemes wears off rapidly, and such schemes have a negative impact on efficiency. Such pure earnings sharing plans mimic rate-of-return type regulatory schemes, as far as their behavioral consequences are concerned, and their impact can be just as detrimental to economic performance as the impact of rate-of-return regulation.

4.2 Impact of the Control Variables on Technical Efficiency

The implications of the results obtained are discussed with respect to the control variables which turn out to be significant. The DEA models make no assumptions with respect to the underlying technology characteristics inherent in the operating data of the observations evaluated, and a finer measure of technical change, *FIBER*, has been introduced as a regressor. The finding that technical change has a strong and positive impact on efficiency is not counter-intuitive, but prior work in this area has been unable to control for aspects of firm-level technical change that has been continuously taking place in the industry. Inappropriate measures, such as a simple time-trend or the aggregate R&D spending at Bell Laboratories, have been used to capture technical change (Waverman, 1989), and the finding in this study, that new technology adopters do perform better, albeit after a one-period lag because of the existing size of the installed-base of the older technology, is arrived at after disaggregated analysis using relevant data.

An important dimension of the political economy in the U.S. telecommunications industry is the nature of the separations and settlement regime that each operating company faces. This regime describes the extent to which total network costs can be allocated to the federal jurisdiction. *SEPARATION* is positive in two of the equations but not significant, since price regulation may have greater impact on firms' behavior and performance. On the other hand, *TOLL CALL* is positive and significant. Toll calls are more profitable than local calls and in inter-LATA and intra-LATA toll markets competitive forces are quite intense, with the intensity exacerbating everyday. Companies processing a greater proportion of toll calls face strong threats of entry from new players, since these companies operate in relatively more lucrative markets, and such threats do seem to induce the firms to be relatively more efficient.

The extent of business lines, *BUSINESS LINE*, does not induce efficiencies suggesting that there are diseconomies in serving idiosyncratic customer needs. *SWITCH SHARE* is negative and firms with greater institutionally-granted market power do perform worse than those without such power, a finding consistent with economic theory (Scherer and Ross, 1990). *SIZE* is negatively correlated with performance. The dependent variable evaluated is pure technical efficiency, irrespective of scale effects, and the results imply that organizational diseconomies characterize local operating company operations. Some of the local operating companies are individually larger than the PT&T administrations of many of the smaller OECD countries, or are large as well as operate in a number of states. Operational coordination and managerial communications may not necessarily be effective in such organizational settings, and the results also call into question the recent penchant of many regional holding companies, such as Ameritech or U.S. West, in consolidating several of their stand-alone local operations into one entity.

OWNERSHIP is positive and whether the companies are one of the Baby Bells or not strongly influences performance, with the non-Baby Bells being less technically efficient than the Baby Bells. Studies highlight post-divestiture transformation taking place at the Baby Bells (Schlesinger, Dyer, Clough and Landau, 1987) and the results obtained provide corroboration as to the comparatively superior resource-utilization capabilities of the Baby Bells. Greater levels of spending on human capital, *COMPENSATION*, and on creating corporate capabilities, *CORPORATE COSTS*, is positively associated with efficiency. While no measures exist as to the relative quality of human capital in each company, the results support the assumptions that greater compensation paid for superior skills possessed, and payment of efficiency wages, helps in selecting those employees whose contribution will make a difference.

4.3 Impact of Incentive Regulation on Scale Efficiency

Descriptions of the explanatory variables in section 3.4 include a discussion of their expected impact on technical efficiency. However, a measure of scale efficiency is also calculated for each observation. The concept of scale efficiency measures the extent to which firms deviate from their most productive scale size, the point on the cost curve where constant returns to scale exist, though firms may be either enjoying increasing returns or suffering from decreasing returns if they are scale inefficient. Scale efficiency, as calculated using DEA, is a measure of the convergence of the present scale of operations to the most productive scale size attainable by firms, with cost savings to be made by scaling up or down if greater scale efficiencies are enjoyed (Banker, Charnes and Cooper, 1984). Equations 7 to 12 detail regression results where the dependent variable is scale efficiency.

Like its impact on technical efficiency, the introduction of incentive regulation has a positive though weaker impact on scale efficiency. *PRICE CAP* is positive and significant, with a two-period lag, at a 90 percent level of significance, though positive in most of the other specifications, while *SHARING & CAP* is either negative and significant or not significant. Conversely, *SHARING* is significant in more of the specifications. These results suggest that hysteresis effects in the local operating sector may be in existence, since the introduction of incentive regulation, or a combination of incentive regulation and earnings sharing, does not significantly impact on the ability of firms to enjoy greater scale efficiencies. On the other hand, the introduction of an earnings sharing scheme, similar in nature to rate-of-return regulation, has more of an impact since the scheme is less novel than that of pure incentive regulation, yet there may be enough novelty in influencing firms' behavior towards attaining scale efficiency.

4.4 Impact of the Control Variables on Scale Efficiency

The control variables have interesting effects on scale efficiency. Those that turn out to be significant are discussed in detail. The diffusion of technical change, as captured by *FIBER*, is positively related to the ability of firms to be scale efficient. Since attaining higher scale efficiency means scaling up or down, new technology does permit forms to be flexible in doing so. *SEPARATION* is strongly significant; reduction of operating costs is a necessary requirement for firms where a greater proportion of the investment is allocated to state-level jurisdictions, as earlier discussed. *TOLL CALL* and *BUSINESS LINE* are positive and significant, which suggest that the possible threat of entry by new players into the toll market and the threat of customer bypass induces efficiencies, attained through a reduction of average costs by being scale efficient.

SWITCH SHARE and *SIZE* are both positive and significant. The former result suggests that the availability of a larger territorial jurisdiction permits network externalities to be gained, while the latter result controls for the property that scale efficiency is a function of size. The result has to be contrasted with the negative result obtained for *SIZE* and technical efficiency, which implied that there are managerial diseconomies facing large firms in the sector. *OWNERSHIP* is negative and significant, implying that Baby Bells find it harder to scale up and down compared to the independent companies which are often smaller and more focussed in their operations. This result contrasts with the impact of *OWNERSHIP* on technical efficiency. Baby Bells are superior in resource utilization, but less able to manage capacity in scaling operations, up or down as necessary, to enjoy scale efficiencies. Finally, *CORPORATE COSTS* is positive and significant in two of the equations, implying that corporate development activities do pay-off in enhancing the abilities of firms to enjoy scale efficiencies.

5. CONCLUSION

This paper has investigated whether the introduction of state-level incentive regulation schemes, operationalized as price caps, has made an impact on the productive efficiency of local operating companies in the U.S. telecommunications industry. Technical and scale efficiency is measured, using data envelopment analysis, for the period 1988 to 1993 and the key results obtained are as follows; first, the introduction of price cap schemes alone has had a strong and positive, but lagged, impact on the technical efficiency of local exchange carriers. Second, where price cap schemes are introduced in conjunction with an earnings sharing scheme, a mode of regulation similar to rate-of-return regulation, then, though there is a positive and more immediate impact on technical efficiency, the impact is less strong compared to the impact of a pure price cap scheme alone. Third, where only an earnings sharing scheme is introduced, its impact over time is found to be detrimental to technical efficiency. Fourth, weaker though broadly positive results are obtained with respect to the impact of incentive regulation on scale efficiency.

The results reveal that the policy switch involving a regulatory natural experiment seems to have worked. At the research level, however, two issues need following-up. The present study uses recent data, with a very short time-series, and the regulation experiment underway is still in the process of unfolding in various states. First, as more states convert to incentive regulation, it is necessary to assess whether lag effects disappear, as firms join the bandwagon in speedingly accepting these regulatory schemes and changing behavior appropriately. Second, price cap schemes operate for a finite period. Since regulatory lag length positively impacts performance (Vogelsang, 1989), an issue in designing incentive regulation schemes revolves around optimal lag length, which empirical analysis relating lag length to efficiency may help elucidate.

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TABLE 1: Description of Variables

VARIABLE	DESCRIPTION
PRODUCTIVE EFFICIENCY	The log of the technical and scale efficiency scores, computed using DEA, for each firm-level observation for the years 1988 to 1993. (Source: Computed by the author using data in FCC Common Carrier Statistics [CCS]).
PRICE CAP	A variable which for single-state operating companies equals 1 if pure price cap regulation exists in the state that the company operates in, and 0 otherwise; for multi-state operating companies a composite index variable is constructed, with 1 denoting the existence of pure price cap regulation, and 0 otherwise, for each of the states the company operates in, by weighting the presence of price cap regulation in each such state by the proportion of total loops contributed by that state to the total number of local loops operated by the company. (Source: Greenstein, McMaster and Spiller, 1994 [GMS] and FCC 1993 Monitoring Report).
SHARING & CAP	A variable that for single-state operating companies equals 1 if price cap regulation combined with an earnings sharing scheme exists in the state that the company operates in, and 0 otherwise; for multi-state operating companies an index variable is constructed following the approach used for the *PRICE CAP* variable. (Source: GMS and FCC 1993 Monitoring Report).
SHARING	A variable that for single-state operating companies equals 1 if an earnings sharing scheme exists in the state that the company operates in, and 0 otherwise; for multi-state operating companies an index variable is constructed following the approach used for the *PRICE CAP* and *SHARING & CAP* variables. (Source: GMS and FCC 1993 Monitoring Report).
FIBER	The percentage of fiber optic lines relative to the total lines that are operated by an operating company. (Source: FCC CCS).
SEPARATION	The percentage of an operating company's total investment that is allocated to the intra-state jurisdiction via the separations process. (Source: FCC 1993 Monitoring Report).
TOLL CALL	The percentage of toll calls relative to the total number of calls for each operating company. (Source: FCC CCS).
BUSINESS LINES	The percentage of business lines relative to the total number of lines for each company. (Source: FCC CCS).
SWITCH SHARE	The percentage of switches operated by each company relative to the total switches that are operated in its operating territory. (Source: FCC CCS).
SIZE	The log of deflated total revenues for each company. (Source: FCC CCS).
OWNERSHIP	A dummy variable which equals 1 if the observation is one of the Baby Bell companies and 0 otherwise if an independent operating company. (Source: FCC CCS).
COMPENSATION	The average $ value of compensation cost per employee. (Source: FCC CCS).
CORPORATE COSTS	The percentage of costs spent on corporate development activities relative to the total operating costs of each company. (Source: FCC CCS).

TABLE 2: REGRESSION ESTIMATES

Dependent Variable: Technical Efficiency Score (t-statistics in parentheses; * $p < .10$ and ** $p < .05$)

Variable	Eq. 1	Eq. 2	Eq. 3	Eq. 4	Eq. 5	Eq. 6
Constant	-0.381 (18.27)	0.465 (0.87)	-0.389 (21.84)	1.080 (2.00)	-0.418 (21.04)	-0.021 (0.04)
PRICE CAP	-0.021 (0.06)	-0.024 (0.57)	-0.010 (0.27)	-0.047 (0.97)	-0.019 (0.47)	-0.090* (1.49)
PRICE CAP_{t-1}			0.036 (0.64)	0.040 (0.56)	-0.112 (1.10)	-0.153* (1.42)
PRICE CAP_{t-2}					0.239** (1.80)	0.290** (2.07)
SHARING & CAP	0.093** (2.41)	0.107** (2.50)	-0.019 (0.43)	-0.008 (0.16)	0.021 (0.40)	-0.067 (1.17)
SHARING & CAP_{t-1}			0.088** (2.12)	0.082* (1.63)	0.063 (1.11)	0.061 (0.94)
SHARING & CAP_{t-2}					0.191** (4.04)	0.160** (2.83)
SHARING	-0.007 (0.43)	0.001 (0.06)	0.062** (1.79)	0.070** (1.75)	0.089** (2.02)	0.126** (3.81)
$SHARING_{t-1}$			-0.045** (2.34)	-0.023 (0.90)	-0.027 (0.57)	-0.059* (1.46)
$SHARING_{t-2}$					-0.080** (2.53)	-0.084** (3.57)
FIBER		-0.519* (1.42)		-0.069 (0.17)		0.144 (0.38)
$FIBER_{t-1}$				0.801** (4.47)		0.766** (5.37)
SEPARATION		0.324 (0.37)		-.691 (0.85)		0.350 (0.38)
TOLL CALL		0.004** (4.77)		0.004** (3.88)		0.010** (7.32)
BUSINESS LINE		0.005 (0.48)		0.001 (1.02)		-0.001* (1.61)
SWITCH SHARE		-0.001** (2.76)		-0.002 (2.71)		-0.001** (2.07)
SIZE		-0.092** (4.15)		-0.078** (4.10)		-0.079** (4.53)
OWNERSHIP		0.349** (5.51)		0.244** (4.11)		0.262** (5.01)
COMPENSATION		0.001 (0.69)		0.001 (0.57)		0.001** (1.29)
CORPORATE COSTS		0.002 (1.26)		0.002 (0.96)		0.008** (4.09)

TABLE 3: REGRESSION ESTIMATES

Dependent Variable: Scale Efficiency Score (t-statistics in parentheses; * $p < .10$ and ** $p < .05$)

Variable	Eq. 7	Eq. 8	Eq. 9	Eq. 10	Eq. 11	Eq. 12
Constant	-0.304	-4.016	-0.334	-4.552	-0.302	-3.375
	(21.46)	(6.80)	(33.10)	(10.78)	(22.04)	(6.27)
PRICE CAP	-0.006	-0.001	0.027	0.031**	0.006	0.019
	(0.21)	(0.02)	(1.12)	(1.77)	(0.26)	(0.84)
PRICE CAP$_{t-1}$			0.022	0.007	0.027	0.022
			(0.69)	(0.37)	(0.97)	(0.89)
PRICE CAP$_{t-2}$					0.094*	0.004
					(1.45)	(0.07)
SHARING & CAP	-0.022*	-0.061**	-0.026	-0.039*	-0.018	-0.159**
	(1.23)	(1.72)	(0.70)	(1.58)	(0.45)	(3.99)
SHARING & CAP$_{t-1}$			0.029	-0.020	0.029	-0.004
			(0.74)	(0.92)	(0.84)	(0.14)
SHARING & CAP$_{t-2}$					-0.031	-0.043
					(0.71)	(1.09)
SHARING	0.016	0.005	0.034	-0.004	0.060**	-0.095**
	(1.14)	(0.27)	(1.09)	(0.17)	(1.89)	(2.77)
SHARING$_{t-1}$			0.047**	0.016	0.042*	0.004
			(1.73)	(1.06)	(1.56)	(1.16)
SHARING$_{t-2}$					0.068**	0.029*
					(2.36)	(1.38)
FIBER		-0.133		-0.481**		-0.610**
		(0.76)		(2.16)		(2.60)
FIBER$_{t-1}$				0.717**		0.444**
				(3.07)		(1.78)
SEPARATION		2.402**		3.051**		2.572**
		(2.90)		(4.82)		(2.95)
TOLL CALL		0.002**		0.001*		0.003
		(3.60)		(1.61)		(3.03)
BUSINESS LINE		0.002**		0.003**		0.003**
		(2.89)		(3.35)		(3.29)
SWITCH SHARE		0.002**		0.002**		0.002**
		(4.05)		(6.49)		(4.18)
SIZE		0.138**		0.129**		0.097**
		(8.25)		(10.18)		(6.01)
OWNERSHIP		-0.068**		-0.048**		-0.038*
		(1.64)		(2.47)		(1.51)
COMPENSATION		0.001**		0.001		0.001**
		(2.05)		(1.12)		(2.02)
CORPORATE COSTS		0.001		0.001		0.000
		(0.64)		(0.89)		(0.00)