regulators in the calling for rate reviews. Second, traditional rate of return regulation involves accounting procedures, like the setting of relatively low depreciation rates, that have non-trivial profitability consequences and that impair the incentives to invest. More fundamentally, though, utility regulators have the ability to second guess the need for particular investments, drastically changing the utilities' investment calculus.[4] The *ex-post* nature of investment questioning raises the potential for opportunistic behavior by the regulators. Thus, in the case of telecommunications, a LEC subject to the potential for such opportunistic behavior will be careful not to devote substantial investments to new technologies, i.e., fiber-optics, which regulators may, in a few years, declare "unprudent and unnecessary." Thus, while rate-of-return regulation may reduce incentives to cut costs, it may further reduce the incentives to introduce modern, and capital intensive, technologies.

Price Cap Methods

Regulatory methods that decouple prices from short term profits, like price-cap regulation, may provide LECs the right incentive to cut costs and innovate.[5] Price cap rather than profit regulation also has the advantage of providing the regulated firm with some amount of pricing flexibility. Such pricing flexibility would allow the firm to rebalance its prices to increase the

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[4] See, for example, Teisberg, E.O., 1993 "Capital Investment Strategies under Uncertain Regulation," Rand Journal of Economics, Vol 24, No. 4, pp: 591-604; Lyon, T.P. 1991, "Regulation with 20/20 Hindsight: 'Heads I Win, Tails You Lose'?" Rand Journal of Economics, Vol 22, No.4, pp: 581-295, and Spiller, P.T. 1993 "Institutions and Regulatory Commitment in Utilities' Privatizations," Industrial and Corporate Change, Vol 2, No.3, pp:387-450.

[5] See Cabral, L. and M. Riordan, "Incentives for Cost Reduction under Price Cap Regulation," 1989 Journal of Regulatory Economics, Vol 1, pp: 133-147 for a theoretical comparison of the efficiency properties of price cap and rate of return.

usage of price sensitive service segments, to appropriately price and introduce new products (e.g., call waiting, call forwarding, answering and faxing services), and to compete more effectively with alternative service providers. In turn, the potential for introduction of new products and an increased competitiveness in relatively contested segments increases the LEC's demand for digital infrastructure.[6]

The efficiency implications of price cap regulation depend on several factors: the extent to which individual prices or basket of prices are subject to price caps; the magnitude of the productivity factor (the x in the British RPI-X system) in comparison to the level of underlying potential for cost cutting; and the periodicity and the considerations that enter in the review of the price cap regime. To a large extent, the process for reviewing price cap regimes is the cornerstone of price cap regulation. Systems of price regulation that review the x-factor very frequently based on the profitability performance of the company will have efficiency properties very close to those of rate of return regulation. The company will have a lower incentive to improve its efficiency if it anticipates that cost reductions will translate into immediate

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[6] There is, by now, a vast literature on the properties of price cap, starting with the work of Vogelsang, I. and J. Finsinger, 1979 "A Regulatory Adjustment Process for Optimal Pricing by a Multiproduct Monopoly Firm," Bell Journal of Economics, Vol 10, pp:157-171. Further work along the "mechanism design" approach is found in the 1989 Vol 20 Rand Journal of Economics Symposium on Price Cap Regulation. See also, Breautigam, R.R. and J.C. Panzar, 1993, "Effects of the Change from Rate of Return to Price Cap Regulation," American Economic Review, Vol 83, No. 2, pp:191-198. Apart from the initial work of Vogelsang and Finsinger, most of the recent literature has assumed that regulators have substantial informational processing capabilities and flexibility to impose prices and make transfers (for an exception, which we discuss in more detail below, see Schmalensee, R, 1989, "Good Regulatory Regimes," Rand Journal of Economics, Vol 20, No.3, pp: 417-436). The nature of these assumptions raises questions about the policy relevance of the different theoretical constructs.

recalibration of the regime and consequent price cuts.

Price Stabilization Schemes

An extreme case of a price cap is a price freeze or stabilization plan. In this type of plan, the company is required to hold the prices of its non-competitive services capped at a certain level. While usually the company may reduce rates below those nominal caps, the company commits not to increase its prices for a certain period of time. These plans usually arise as part of a "social contract" arrangement between the state Commission and the regulated company. The company's promise not to increase prices is accompanied by a Commission proposal to either not subject the company to a rate review throughout the period, or to provide the company with an earnings sharing scheme that allows it to increase its current profitability. Price stabilization schemes may not be sustainable if large economy wide price shocks threaten the profitability potential of the company. This risk, however, is absent in price-cap methods whose indexation features provide for a cushion against macro-economic shocks. In low inflation environments, though, the main difference between price cap and price freeze regimes is that while the former type provides for rebalancing of rates, the latter does not.

The relevance of rate rebalancing depends on the extent of cross-subsidies inherent in the initial price structure, and on the degree of competition in the non-regulated segments. Absent a strong need for rebalancing, and in the presence of low inflationary pressures, a price cap scheme with x close to the inflation rate, and a price freeze scheme may turn out to provide similar incentives. On the other hand, in the presence of large cross-subsidies, price-cap regimes, by

allowing rate rebalancing, may provide stronger investment incentives to the LEC. Finally, price cap regimes that have multiple sub-baskets, and that have price increase limitations for individual products may become indistinguishable from price freeze regimes.

Although price cap regimes have superior efficiency features than price freezes, their differential impact on incentives for infrastructure deployment is an empirical matter. In practice, given the low level of inflation throughout the period of analysis, the main theoretical advantage of price cap regulation over price freezes may have simply been the ability to rebalance rates. Below we explore whether in our sample price caps and price freezes provide similar investment incentives to LECs.

Earnings Sharing Schemes

Price regulation is only one aspect of the regulatory environment. Another important aspect is profit regulation. As it is well known, traditional rate of return regulation brings upper and lower bounds to the profitability of LECs. If profits are too low the firm will call for a rate review, while if profits are too high regulators may call for rebates or price reductions. Earnings sharing schemes institutionalize the previous ad-hoc process of rate reviews. A standard earnings sharing scheme is composed of a series of rate of return levels and a corresponding series of excess profit sharing between the company and its customers. For example, California's initial earnings sharing scheme with Pacific Bell and GTE called for two rate of return levels: 13% and 16.5%. The companies will keep all revenues if their profits provide an annual rate of return less than 13%. If their rate of return is between 13% and 16.5%, they will keep 50% of the excess

profits and rebate the excess revenues to their customers. Finally, if their profit levels exceed 16.5% they will rebate all excess revenues over 16.5% and half of the excess revenues in between 13% and 16.5%. In this way, the maximum rate of return that the company can obtain is 14.75%.[7,8] Not all earnings sharing schemes provide for such maximum rate of returns. For example, Mississippi's earnings sharing scheme with Bell South calls for the company returning 50% of all earnings over 11.74%, while keeping all earnings when its rate of return is between 10.74 and 11.74%.

The efficiency implications of different earnings sharing schemes, then, will depend on the underlying economic conditions facing the company, the nature of the rate of return bands, the actual sharing arrangements, and the periodicity of the profit computation.[9] The latter three are usually chosen as the result of bargaining between the state Commission and the regulated company. In principle, it could be feasible to design an earnings sharing scheme that, in a static environment, would motivate the company to undertake the (second-best) optimal level of investment.[10]

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[7] That is composed of the allowed 13% plus 1.75% which represents half the difference between 16.5% and 13%.

[8] As Appendix 1 shows, GTE's earning scheme was changed for 1994-1996 so that it retains 100% of earnings less than 15.5% and rebates to its customers all earnings above 15.5%.

[9] In some states, companies have to make quarterly computations of rate of return. See Appendix 3.

[10] See Schmalensee, *supra note* 5, for a study showing that in a static (although uncertain) environment where regulators can commit to a particular cost sharing scheme, simple cost sharing has some advantages over simple price regulation. The main reason for the superiority of cost sharing over price regulation is that under price regulation unexpected cost

The "optimal" sharing rules, however, are complex, and require extensive information by the regulators. They involve flexible and, to some extent, counterintuitive pricing rules (e.g., high prices in "bad" states and low prices in "good" states of nature) and substantial lump sum payments among customers and firms.[11] Such complex schemes are not easily implementable both for practical and political considerations.[12] Simpler earnings sharing schemes, although more easily implementable, have substantially weaker efficiency properties.

Furthermore, the regulatory complexity of the schemes has to be taken into account when considering its overall cost and benefits. Earnings sharing schemes require the continuous monitoring of the LEC's profitability. As a consequence, they may eliminate the traditional regulatory lag associated with rate of return regulation.[13] Thus, although formally earnings

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increases may force the firm to decide not to produce. To prevent such events, the initial markups have to be set relatively high. Cost sharing provides for lower initial markups, thus increasing consumer welfare. While Schmalensee's argument is appropriate when analyzing price-freezes, it does not carry over to the analysis of price caps based on indexation. Since, in telecommunications, cost increases arise most probably from economy wide shocks (e.g., labor and material costs) rather than from sector-specific shocks, price caps based on indexation limit the need for increased markups to satisfy the participation constraint of the regulated company. This increase in the initial markup is at the core of Schmalensee's comparative result. In the absence of such need for an increased mark-up, Schmalensee's comparative result does not hold.

[11] These lump sum payments may be positive (i.e., transfers to the firm) or negative (rebates to customers). See Laffont, J.J. and J. Tirole, 1993, A Theory of Incentives in Procurement and Regulation, Cambridge, Mass: MIT Press for a general discussion of "optimal" regulatory schemes when regulators face informational asymmetries.

[12] For example, no legislature will delegate to the state regulatory commission discretion to set annual lump sum payments to the LEC. Furthermore, no commission could be expected to collect the required information and calculate the "optimal value" of such lump sum payments.

[13] Under traditional rate of return regulation State Commissions do not usually call for rate reviews on a continuous basis. As a consequence, LECs capture some short run gains from

sharing schemes may provide LECs with a higher profitability rate than standard rate of return, whether they do so in fact depends on the Commissions' rate review practices.[14] Finally, the continuous monitoring of the company's profitability increases the regulatory burden, with a direct cost to tax- and rate-payers.

Combinations of Price Regulation and Earnings sharing Schemes

The theoretical beauty of price-cap regulation is that regulators do not have to monitor the company's profitability on a continuous basis, and that prices are, at least in the short run, decoupled from costs and profits. This particularly advantageous feature of price cap regulation disappears when it is coupled with an earnings sharing scheme. Indeed, as we discussed above, earnings sharing schemes require regulators to monitor the company's profitability on a continuous basis and to request lump sum rebates if profits are deemed "excessive." Earnings sharing, then, limits the incentive features of price-cap because the profit increases associated with cost cutting, rate rebalancing and the introduction of new products may now be partially or totally taxed. If the latter is the binding case, though, there will be no difference with a rate of return regime where the allowed rate of return is set to the higher bound. Although the pricing flexibility associated with price-caps may have superior properties to the pricing flexibility

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cost reductions. These incentives to cut costs will be eliminated by an earnings sharing scheme that continuously monitors thecompany's profitability.

[14] Indeed, it is not surprising that in several states where State Commissionshave offered LECs the opportunity to move away from rate of return towards earnings sharing schemes, most of the smaller LECs have chosen not to propose incentive plans.

associated with the traditional rate reviews,[15] these advantages may provide only second order efficiency effects when profits are constrained. Indeed, it is possible to imagine that the combination of price cap and earnings sharing provides less investment incentives than either price cap or earnings sharing by themselves. Consider, for example, an earnings sharing scheme with a very narrow profitability band.[16] The narrowness of the band implies that there is not much difference between earnings sharing and rate of return.[17] Superimposing on that regime a price-cap system further constrains the feasible profitability of the company, thus limiting its investment incentives.

Similarly, a price freeze coupled with an earnings sharing scheme may have even worse properties than an earnings sharing scheme by itself. Indeed, because a price freeze exposes the company to cost shocks beyond its control while the earnings sharing scheme may substantially limit its upward profitability potential, firms may find price freezes coupled with earnings sharing schemes a riskier environment than straightforward rate of return, and may, as a consequence, limit their investment program.

To summarize, we have discussed three general incentive regulation schemes: price-cap,

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[15] In standard rate of return reviews effort is made to accomplish what may be an almost impossible task: separating LECs costs on a product by product basis. On a price-cap regime such attempts are obviated.

[16] See below for a more in-depth discussion of the economics and practice of earnings sharing methods.

[17] Connecticut's current regulation of SNET may fit that description. See Appendix 2.

price freezes or stabilization schemes, and earnings sharing. In principle, price cap regimes should provide stronger incentives than price freezes and the latter, in turn, should provide stronger incentives than earnings sharing schemes. Furthermore, coupling earnings sharing with price freezes or price cap may degrade regulatory performance from price regulation alone, and even from earnings sharing alone. Since the actual schemes chosen by state Commissions are, in all likelihood, not the optimal ones, it is an empirical matter which method (or combination) provides stronger incentives for cost cutting and investment.

III. THE EVOLUTION OF THE STATES' REGULATORY ENVIRONMENT

Price and profit regulation are only two of the many dimensions of states regulation of telecommunications. State Commissions regulate not just prices and profits but also the extent of competition in new and contested segments. For example, they regulate the extent of permissible bypass, whether to treat dominant firms differently, whether to allow intraLATA competition, whether to deregulate competitive services, whether to provide for local exchange competition (including the entry of competitive access providers), etc., etc.[18]

Figure 1 depicts the evolution of the states' regulatory environment. The figure shows for each regulatory policy the number of states that have implemented those types of policies. We observe an upward trend in the implementation of all those regulatory policies. Indeed, by all measures, the states' competitive environment is much more intense and their regulatory policies

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[18] See, Huber et al (1993) for a description of the variety of regulatory instruments at the state level.

are much more flexible in 1993 than a decade ago. For example, while in 1984 only ten states allowed intraLATA competition, by 1993 almost forty states allow it. Similarly, by 1993 thirty states had introduced policies to liberalize services deemed competitive. The figure also shows the spread of competitive access providers, with almost twenty states allowing such entry by 1993. The movement towards a more competitive environment is accompanied by a trend towards more flexible regulatory schemes. Thus, while in 1984 there was no state that had introduced an incentive regulation plan, by 1993 approximately twenty states had introduced some type of price regulation and almost thirty had introduced earnings sharing schemes.

These numbers, however, disguise the fact that state Commissions do not implement their flexible regulatory schemes throughout their respective states, but rather that they are implemented on a firm by firm basis. Indeed, only a handful of states (e.g., Nebraska in 1986) have taken a state wide approach to regulatory reform. Figures 2 and 3 provide a graphic proof of the state of incentive regulation across the country in 1991. The figures show that price regulation and earnings sharing schemes were implemented on a firm by firm basis. Indeed, they show also that in most cases, flexible regulatory schemes were introduced only for the dominant firm, as GTE and the other large independent companies seldom were the beneficiaries of major regulatory reforms.[19,20]

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[19] Several states, however, undertook special regulatory reform for small telecommunications firms. For example, a 1988 Indiana law allows for price deregulation of local exchange companies with less than 6,000 lines. Similarly, in 1987 the South Dakota legislature deregulated all cooperatives and LECs with less than 10,000 lines. In this paper, however, we focus on the large LECS, those with sales of $100 million or more per year.

The trend towards more competition and more flexible regulation at the state level requires an analysis of the relative performance features of the different regulatory frameworks introduced by the states. In this paper we attempt to start this investigation by focusing on their impact on digital infrastructure deployment.

IV. AN EMPIRICAL FRAMEWORK

Main Empirical Hypotheses

The discussion in section III suggests several main hypotheses about the role of incentive schemes in promoting modern infrastructure deployment. The most simple hypothesis is that incentive schemes provide extra investment incentives to LECs, whereby incentive schemes we mean the presence of either price regulation or earnings sharing schemes. A second hypothesis disaggregates incentive schemes into price regulation and earning schemes. Our previous discussion suggests that price regulation should provide, on average, stronger investment incentives than earnings sharing schemes. Furthermore, price-cap regulation should provide stronger investment incentives than price stabilization plans. Finally, our discussion suggests that combining price regulation and earning schemes should degrade the incentive effects of price regulation. Under some conditions, it could also be the case that price regulation combined with earnings sharing diminishes overall investment incentives as compared to each scheme separately.

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[20] In a few states, however, only a non-RBOC company was subject to an incentive scheme. In New York, for example, after NYNEX's incentive regulation plan was abandoned because of financial difficulties, the Commission agreed to an incentive regulation plan for Rochester Telephone.

Data Requirements

Because incentive schemes are not state-wide but rather they are firm specific, any attempt to explore the implications of incentive schemes has to identify the regulatory schemes faced by each individual company. Since holding companies are multi-state operations, infrastructure deployment at the level of the holding company would not be of much use in isolating the impact of the regulatory environment. Consider, for example, Ameritech, the operator of the regional Mid Western holding company. In 1991 Wisconsin Bell operated under a price stabilization plan, which freezed rates except for unusual macroeconomic circumstances. All of Ameritech's other state operations had, at that time, no price based incentive regulation plan. In the absence of state level information on infrastructure deployment, the effect of Wisconsin's price stabilization plan would be almost impossible to isolate. In particular, pro-rating Ameritech's deployment of digital infrastructure among its different LECs would arbitrarily assume that the 1991 plan provided no particular investment incentive. Thus, firm/state level information is key to estimate the effect of the regulatory environment on infrastructure deployment.

Since infrastructure deployment is affected not only by regulatory, but also by the economic (demand and cost) circumstances in which a LEC operates, estimating the impact of the regulatory environment requires the identification of the firm's specific economic environment. In particular, state wide economic information will, in general, bias the results. This bias will be aggravated if there is a correlation between the firm's economic and regulatory environment. Finally, as mentioned above, the regulatory environment includes a multiplicity of policies. To separate the effect of incentive regulation from the other regulatory policies, it is important to

identify the key components of the regulatory environment facing each individual firm.

To summarize, because incentive regulation plans are firm specific rather than state-wide policies, state- or holding company-wide information on infrastructure deployment is inappropriate for the task at hand. Indeed, to isolate the effect of incentive plans, information on economic conditions in the franchise territory of each company has to be ascertained. We describe in detail, below, the nature and sources of our data.

The Econometric Framework

The basic framework to measure the effect of the regulatory structure on long run infrastructure deployment is the estimation of a pooled cross-section time series equation of the following form:

$$Y_{kjt} = X_{kjt}\beta + \epsilon_{kjt}, \qquad (1)$$

where Y reflects the actual level of infrastructure of the local exchange company k in state j at time period t, and X reflects a matrix of explanatory variables, such as regulatory, market (demand), and cost conditions, which also differ across local exchange companies, states, and time period. ϵ is assumed to be a well-behaved error term. Equation (1) is inappropriate, however, when dealing with rapidly growing infrastructure deployment, where the implicit assumption of long run equilibrium does not hold. Indeed, as Figure 1 shows, all our measures of modern infrastructure experience extremely rapid growth, in the range of 40 to 100% a year. In these circumstances, it becomes more interesting to attempt to explain the extent of differential infrastructure growth across LECs.

To analyze the determinants of differential growth we take two related, but distinct, statistical approaches. With relatively long time series for each LEC it is possible to attempt to estimate an investment adjustment model. Investment adjustment models assume that the current stock level is a weighted average of the long run desired stock level and of the lagged stock value, where the weights reflects the speed of adjustment to long run equilibrium. That is, let Y^*_{kjt} reflect the log of the long run desired stock level of the infrastructure measure for firm j in state k in time period t. Let, furthermore, Y^*_{kjt} be given by

$$Y^*_{kjt} = X_{kjt}\,\beta + \epsilon_{kjt}\,. \tag{2}$$

Current levels are given, however, by the adjustment process:

$$Y_{kjt} = Y_{kjt-1} + \alpha(Y^*_{kjt} - Y_{kjt-1}) + \mu_{kjt}\,. \tag{3}$$

Substituting (2) into (3) we obtain

$$Y_{kjt} = \alpha' Y_{kjt-1} + X_{kjt}\,\beta' + \upsilon_{kjt}. \tag{4}$$

where $\alpha' = 1-\alpha$, $\beta' = \alpha\beta$ and $\upsilon = \alpha\epsilon_{kjt} + \mu_{kjt}$.

Estimation of (4) provides information on two aspects of the investment process: first, the estimate of α reflects the speed of adjustment. When α' is close to zero, the adjustment to the long run desired stock level is immediate, while when α' is close to one the adjustment is very slow. Second, the estimates of β (recall that $\beta=\beta'/\alpha$) provide information on the effects of the regulatory and economic variables on the long run desired stock level.

As inspection of (4) makes clear, without sufficient time series variation per firm in Y_{kjt}, it may not be feasible to separate the contribution of the lagged dependent variable from that of the current regulatory and economic effects. In particular, if α is measured imprecisely (that is, with large standard errors) or if its estimated value is relatively small, then β will not be estimated very precisely. Accurate estimation of α, however, requires a relatively long time period. For that reason, we attempt to estimate (4) only for fiber optic cable deployment, for which information per LEC is available from 1986 to 1991.

Our second approach attempts to explain the differential growth in infrastructure deployment across LECs. Because growth will depend on initial conditions, we redefine our left hand side variable as the change in infrastructure deployment from a base year. We select the base year as that year in which LECs were required to start reporting their deployment of that particular technology to the FCC. The base year for fiber is then 1986 and is 1989 for the other digital technologies. Thus, our baseline growth model, which modifies equation (1) becomes:

$$Y_{kjt} - Y_{kjb} = X_{kjt}\beta + \epsilon_{kjt}, \text{ for } t>b \qquad (5)$$

where b stands for base year.

The estimates of β in equation (5) show the impact of regulatory and other economic variables in infrastructure growth from the baseline year. Thus, the comparative statics exercises associated with (4) and (5) are quite different. While in (4) a change in X is associated with a β increase in the long run stock level of the infrastructure measure, in (5) such change is associated with a β increase in the stock level over its base year. Thus, while (4) could allow us to make

cross-LEC statements (e.g., "better regulatory conditions double the level of fiber optic deployment"), estimates of (5) allow us to make within-LEC statements (e.g., "better regulatory conditions double the growth rate of fiber optic deployment from the base year"). If base year levels of the infrastructure measure were small and randomly distributed across the LECs, and if α in (4) was relatively high, then estimation of (4) and (5) would provide very similar inferences. As we will see below, the inferences for fiber optic deployment from either statistical procedure are not that different. Because for the other three infrastructure measures information is available only for 1989 to 1991, we cannot make the comparison between the two methods, and instead we attempt to estimate only the determinants of growth over the base year of 1989.

V. DATA

We undertake our analysis at the local exchange company. We use two main sources of information. For local-exchange company specific information we use the data developed by Greenstein, McMaster and Spiller (GMS).[21] For the regulatory environment, we combine the compilation of state regulations undertaken separately by GMS and by LECG. We describe these data sets in turn.

GMS gathered two types of company-state specific information: financial and operational information (including infrastructure information) for each LEC in each state, and demographic characteristics for each of the LEC's territories in each state. GMS collected their information for

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[21] S. Greenstein, S. McMaster and P.T. Spiller, "LEC Specific Regulatory and Economic Environment," University of Illinois, 1993.

the period since divestiture. Because demographic information is available only until 1991, and most of the relevant digital infrastructure data start to be reported only in 1986, our current data set covers the period 1986-1991.

GMS gathered operating, infrastructure and financial statistics for all those LECs that file annually with the FCC for each state they operate in using forms M and ARMIS 43-03, 43-04 and 43-07 (Alaska, and Hawaii were excluded). There are 101 local exchange carriers in each year of the GMS data.[22] The demographic information was collected at the county level, and was then assigned to the dominant carrier within its boundaries according to maps showing the local exchange carriers' territories in each state.[23] The county data are then aggregated to the company level within each state.[24] The main source of the demographic (county level) data is the Annual Estimates of the US Bureau of Economic Analysis, Department of Commerce, "Regional Economic Information Systems Annual CD," and the Bureau of Labor Statistics' Employment and Earning Annual Reports.

Endogenous Variables

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[22] Only companies that earn over $100 million in revenue are required to report to the FCC. ARMIS 43-07 filings, however, further restrict our sample as only carriers subject to price-cap regulation are required to file information on installation of digital switches and associated technologies (ISDN, SS7).

[23] GMS collected all forty eight state maps from the states' regulatory commissions and main telephone companies.

[24] Although it is often the case that more than one carrier is operating in a county, over the entire state these discrepancies tend to average out, thus eliminating any major biases.

We use four different measures of infrastructure deployment: ALL FIBER, DIGITAL SWITCHES, ISDN and SS7. Except when state otherwise, all variables are measured in logs. See Table 1 for a summary description of the data. ALL FIBER is defined as the total miles of fiber optic cable deployed by the company within the state.[25] Fiber optic cable allows for high speed transfer of voice, video, and data transmissions.[26] Fiber optic deployment is identified at the company level for each firm in each state.

DIGITAL SWITCHES represent the deployment of digital stored program controlled switches (DSPC). DSPCs are computers that are assemblies of equipment designed to establish connections between lines and trunks. They provide the intelligent interface between subscriber lines and other parts of the network. Although switches have been a part of the local exchange carrier's equipment since the inception of the telephone network, digital switches allow for a higher volume and better quality. Digital switches enhance the ability of the firm to offer specialized and custom local area signaling services -- call waiting, call forwarding, caller ID, variable ringing patterns, call blocking and call tracing.[27]

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[25] This measure includes both fiber optic cable that is currently in use ("lit" fiber) and that which has been deployed but is not yet operational ("dark" fiber).

[26] Fiber optic cable is a high speed, high quality transmission mechanism that is limited in capacity only by the available terminal and repeater technology. It is purified silica glass using laser chips. Erbium-doped fiber amplifiers enhance the capacity to tens of thousands of gigabit-kilometers per second. It is reported in Annual Form-Ms filed with the FCC and it is measured in fiber miles.

[27] It is reported in ARMIS 43-07 reports filed annually with the FCC. It is measured as total DSPC switches.

ISDN refers to Integrated Services Digital Network. It is an international standard that allows voice, data, text and video communications to travel simultaneously down the same transmission path. Its use will be facilitated by the implementation of digital technology and the adoption of SS7. It is an engineering concept that contemplates a public, end-to-end switched digital network in which time division switches and digital transmission paths accommodate multiple services originating at subscriber locations.[28]

SS7 refers to Signalling System 7. It is an international standard for out-of-band signaling that conforms to ISDN standard specifications. It is software that facilitates the use of ISDN creating two channels within a single line. This improves the efficiency of a network because less capacity is tied up in the process of connecting a call.[29]

Exogenous variables

Economic and Demographic Data

As mentioned, the demographic data were collected at the state and county level for the continental United States, including the District of Columbia. GMS' demographic data set includes numerous variables that help characterize each area being served by the local exchange carrier. We describe now the economic and demographic variables used in this study.

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[28] It is reported in ARMIS 43-07 reports filed annually with the FCC. It is measured as lines equipped with ISDN.

[29] It is reported in ARMIS 43-07 reports filed annually with the FCC. It is measured in number of switches equipped with SS7. Includes switches equipped with SS7-317 and SS7-394.

LAND MASS reflects the square miles of land area served by the company in that state (in logs). The size of the area being served will tend to increase infrastructure deployment that is measured in miles, although should have no effect on the deployment of digital switches. Land area by itself, however, does not provide a proper picture of the demand for digital infrastructure. Population and income are two other features of the service territory of the LEC which have an impact on the demand for such infrastructure. We use three measures of population. URBANIZED POP represents the population served by the company that lives in cities with population of 50,000 or more. These are the central cities which are the least expensive for the LECs to serve because of their density. We expect URBANIZED POP to increase the demand for digital infrastructure. URBAN POP represents the population served by the company that lives in cities with population of more than 5,000 but less than 50,000. URBAN POP should have a smaller impact on the demand for digital infrastructure than URBANIZED POP. RURAL POP represents the population served by the company that lives in rural settlements comprising populations of less than 5,000. The larger the rural population of the LEC territory (holding constant URBANIZED POP) the higher the probability that most of its population is located in a single metropolitan area. As a consequence, the smaller the need to deploy fiber-optic cable for intraLATA services, and hence we should expect a reduction in the miles of fiber-optic deployment. On the other hand, the higher RURAL POP, the more dispersed the population is, holding constant LAND MASS, affecting the need for infrastructure deployment.

AVG PER CAP INC represents the real average per capita income for the territory served by the LEC in that state. This variable measures the wealth of the LEC's territory and should

reflect the LEC's residential demand for improved service. The demand for digital infrastructure deployment also comes from manufacturing and service industries needs. For that purpose we use two variables: MANU INCOME and FIRE INCOME. MANU INCOME represents the value of real manufacturing earning for the territory served by the LEC in that state. FIRE INCOME represents the real earnings of the Financial, Insurance and Real Estate sectors for the territory served by the LEC in that state.

We measure the cost of infrastructure deployment by HOURLY CONSTRUCTION WAGE which represents the real average hourly construction wage for the territory served by the LEC in that state.[30] The higher the cost of infrastructure deployment, the lower should be its equilibrium value.

A variable that reflects both economic and regulatory forces is NUMB OF LEC that measures the number of LECs serving the state in the GMS data set (firms with at least $100 Million in revenues that report to the FCC). These include Bell, GTE, Contel, Central, and United affiliates and Lincoln Telephone & Telegraph, CBTC, and Rochester Telephone. This variable is intended to provide a measure of potential competition, as well as the potential for benchmark regulation. We would expect both factor to foster infrastructure deployment. Finally,

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[30] A variety of dollar figures are used in the analysis and to ensure their compatibility across the period, they are all converted to 1987 dollars using the Consumer Price Index. In addition to the CPI data, the hourly construction wages data was also obtained from the Bureau of Labor Statistics, in their Employment and Earnings Annual Report. The rest of the demographic data was obtained from the Commerce Department's Bureau of Economic Analysis, Annual Regional Economic Information Systems CD.

since there are idiosyncratic features of the different type of LECs we use dummy variables to capture features of RBOCs and GTE companies.[31]

The State Regulatory Environment: Incentive Regulation

The telecommunications industry has long been regulated in a two-tiered structure. It is regulated both at the federal level, by the FCC, and at the state level by the state Public Utility or Commerce Commission. Although regulations at the federal level have changed uniformly and simultaneously for all states and, generally, for the telecommunications firms operating within them,[32] state level regulation has changed in diverse, non-uniform ways, especially in the last ten years since the divestiture.

State commissions usually derive their authority to regulate through statute. The extent of each agency's authority varies, not only because the language of specific statutes does, but also because the laws are interpreted differently by the agency and the courts within that state. How the agency utilizes their authority, and to what extent they do so, also differs by state. Within the telecommunications arena, the commissions are responsible for a wide variety of regulatory areas, including pricing, bypass, competition, and general restrictions placed on the firms in the industry.

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[31] In preliminary regressions we included a Contel dummy variable but it was never statistically significant.

[32] Because FCC regulations apply to almost all large LECs, identifying the impact of the FCC's price cap regime is almost impossible. In particular, since FCC price caps were introduced in January 1991, the effects of such regulatory change would be subsumed in the 1991year effect.

Incentive regulation is a key component, although not the only one, of the regulatory environment faced by the LECs. Incentive regulation, however, varies drastically across companies, even within a given state. LECG collected,[33] for each LEC since 1986, data concerning whether the LEC is subject to any incentive regulation scheme, whether its prices are regulated by rate review, price caps or are frozen (usually as part of a "social contract" scheme), whether its profits are subject to standard rate of return or sharing schemes. LECG also collected detailed information on general state Commission regulatory policies, that would impact, in principle all telecommunications firms in the state. For example, LECG collected information on whether all products provided by an LEC are regulated or whether the Commission has a policy of deregulating "competitive" segments; whether the Commission allows entry of competitive access providers; whether the Commission restricts bypass; whether the Commission allows competition and resale in the local exchange, intra-LATA, and for multi-LATA states, in the inter-LATA segments of the market.

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[33] LECG undertook a compilation of the regulatory environment of the states since divestiture. Several sources were used. Published sources include NARUC's "Annual Report on Utility and Carrier Regulation, 1986-1990," NARUC's "Compilation of Utility Regulatory Policy, 1991-1992," NARUC's "State Telephone Regulation Report, 1987," NARUC's "Update to the Main and Missouri Reports on Alternative Regulation Plans in Telecommunications," Amy Levins and Brenda Ewers, "Report on Telecommunications Alternative Regulation by State" (the Missouri Report), Joel Shifman and Darby Arseneault, "Maine Public Utilities Commission Report on Telecommunication Alternative Regulation Plans by State" (the Maine Report), Mary Nagelhout's article on "Incentive Regulation of Public Utilities," Public Utilities Fortnightly 7/1/91, Peter Huber's "The Geodesic Network II." Apart from data gathered from published sources, we use the results of a LECG survey of LECs and regulatory commissions. LECG requested from all forty eight regulatory commissions to confirm, and where necessary to expand, on LECG's information on their regulatory environment. Of the forty eight regulatory commissions contacted only five were unable to respond to LECG's questionnaires. LECG also requested information on incentive plans from representatives of all state's main telephone companies.

Appendices 1 and 2 describe all earnings sharing and price regulation schemes that have been implemented since 1984. The large variety of incentive schemes makes it impossible to categorize them in fine detail without evaporating degrees of freedom rapidly. Instead we created three types of incentive regulation variables: price caps, price freezes and earnings sharing. For a LECs regulatory structure to be categorized as a PRICE CAP the LEC has to have the freedom to increase its regulated prices either by a specific formula or by a specified maximum without triggering regulatory action. For example, during the period 1991-1993, GTE and Pacific Bell of California were allowed to increase the prices for their basic and partially competitive products by CPI minus 4.5%.

A LEC's regulatory structure would be categorized as a PRICE FREEZE if its regulated prices are capped at some particular level independent of actual costs. For example, Southwestern Bell of Kansas has its basic residential and business rates frozen until 1995, independent of both actual costs and actual earnings. As the appendices make clear, however, most incentive regulation schemes are not independent of costs or profits, but rather call for continuous monitoring of profitability. Thus, our third incentive regulation categorization is EARNING SHARING. For a regulatory structure to be categorized as earnings sharing the profitability of the LEC must be neither totally capped nor totally unregulated. The first earnings sharing scheme we are aware of was introduced in 1986 by the Alabama Public Service Commission in its regulation of South Central (a Bell South's subsidiary). South Central's scheme allows it to keep earnings of up to 12.3% of capital. Above 12.3% it will share 50% of the excess

with ratepayers.[34] As discussed above, other states have introduced more restrictive sharing arrangements.

The extent by which LECs subject to earnings sharing schemes actually rebated earnings to ratepayers is presented in Appendix 3. The appendix shows that most, but by no means all, LECs subject to earnings sharing did share to some extent. The fact that not all shared is quite illustrative of both the disincentives that are associated with profit sharing schemes and the regulatory burden that they imply. First, the fact that sharing was not widespread and that overall sharing was of small magnitude may reflect either that the sharing bands were very lax, or that the potential for sharing did not sufficiently entice the LEC to innovate and cut costs. Second, the fact that sharing requires a substantial regulatory apparatus which turns out very small rebates suggests that the regulatory cost may exceed whatever regulatory benefit may be associated with profit sharing.

Incentive regulation schemes, then, are combinations of price and profit regulation. Some of the companies in our sample are subject only to price regulation, others to profit regulation and others to a combination of the two. This mixture of incentive schemes is what allows us to identify and separate the effects of specific components of the different incentive regulation schemes. For details on which firms have had price regulation and/or earnings sharing schemes, see Apendices 1 and 2. See also Figures 3 and 4 for similar information as of 1991.

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[34] The extent of sharing, however, could be adjusted depending on how well the company meets service and cost efficiency standards.