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

[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

The Regulatory Environment: General Conditions

Because we are interested in exploring the extent by which incentive regulation influences digital infrastructure deployment, we have to control for the general regulatory environment. Since a complete picture of the regulatory environment cannot be determined from any one policy variable, we consider policies that differ substantially across states. The following set of general regulatory variables is used in the study: 1) unrestricted bypass; 2) entry of competitive access providers; 3) resale of local exchange services; 4) intraLATA competition; 5) deregulation of competitive services, and 6) earnings sharing applied to companies in the state. These variables take a value of 1 if the state Commission has taken a positive policy concerning that regulatory issue. We further include a variable that measures the number of large firms operating in the state.

No Restrictions on Bypass

A state's treatment of bypass can also give a general indication of the state's acceptance of competition within telecommunications. Bypass regulation involves several steps. First, the state must decide whether to allow bypass in general or not. Once a decision has been made to allow bypass of the local exchange facilities, the state must further decide whether or not to place restrictions on those providing the necessary equipment and technology.[35] Our variable *Not Restrict* takes a value of 1 when the Commission places no restrictions on bypass.

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[35] Several states (e.g., Maine) do not allow formal bypass. Others require entry-certificates.

Competitive Access Providers

Competitive Access Providers' (CAPs) facilities allow for bypass of the local exchange network through the provision of transmission services between a building or complex and the point of presence of an IXC. This allows IXCs to avoid the access charges associated with connection to the LECs facilities, thus decreasing costs. Since access charges are currently about one-half of interexchange carriers' costs, CAPs are potentially formidable competitors in the LECs' most important line of business.

Authorizing CAP entry indicates a willingness on the part of the state to accept competition to some extent within the local exchange, at least for the larger users of telecommunications. This, however, raises other issues that the regulators must then face, such as how to allow the LECs to compete with the CAPs, regulation of CAPs, and interconnection of CAPs with LEC facilities. All of these and more must be addressed, as the regulators move toward more competition within the local exchange boundaries.

CAPs did not exist before 1984, and only began to be a factor in telecommunications by 1987. However, by 1991 there were 50 CAPs serving 30 cities, mainly large metropolitan areas, such as New York, Chicago, San Francisco, Los Angeles, and Washington D.C. There has also been some development in the smaller cities, such as Pittsburgh, Seattle, and Dallas. It is important to note though that all CAPs limit their coverage to urban areas, where it is the least expensive to provide services. Our variable *CAP* takes a value of 1 when the Commission allows CAP entry.

Resale of Local Exchange Services

The state's allowance of resale of services also gives an indication of its receptiveness towards freedom in pricing, and thus to competition. Three types of intrastate resale of services can be allowed: intra-state-interLATA toll services; intraLATA toll services; and within the local exchange. As resale is allowed across successively smaller geographic areas, the regulatory environment improves the degree of pricing efficiency, as different types of cross-subsidization schemes become untenable with widespread resale. By 1991, the vast majority of states allowed inter-LATA resale, although some states still limited this to MTS or WATS service. In addition, most states allowed resale of intraLATA services. Resale of local exchange services, however, is still generally not permitted, with only fifteen states allowing it in 1991, and in several of those states it is regulated. Our variable *Resale of LEX* takes a value of 1 when the state Commission allows such resale.

Intra-LATA Competition

Regulators must consider directly whether or not to allow for competition in their state. Their decisions regarding this, like resale, are made for three levels of competition: interLATA, intraLATA, and the local exchange. By 1986, most multi-LATA states had allowed for the competitive provision of intrastate interLATA services, with North Dakota and Pennsylvania allowing its provision in 1988 and 1987 respectively. A great deal of change has been seen over the same time period in intraLATA toll competition with only 18 states allowing for it in 1986, while by 1991 this was up to 33 states. The LATA was seen to be the border between the competitive long-distance market and the "natural monopoly" area of the local market. Thus

acceptance of competition within this border has been slower to occur. This slowness is even more pronounced in the competitive provision of local exchange: only four states, Idaho, Michigan, Montana, and New York, allowed it by 1991. Our variable *IntraLATA Comp* takes a value of 1 when the state Commission allows such competition.

Deregulation of Competitive Services

Finally, as Figure 1 shows, by 1993 deregulation of competitive services has been implemented in thirty states. The deregulation of competitive services usually involve the categorization of telecommunication services in three types: basic, emerging competitive or discretionary, and competitive. Price regulation is then designed in different form for each type of service. For example, a 1992 Michigan law eliminated firm-wide regulation, and directed the Michigan Public Service Commission to regulate products on a product by product level. Substantial price flexibility is then granted to competitive and emerging competitive or discretionary services, while basic services remain strictly regulated.[36] Our variable *Dereg of Comp Serv* takes a value of 1 when the Commission provided for pricing flexibility of competitive services.

Earnings sharing in the State

As we discuss above, most incentive regulation schemes are of a firm-by-firm nature. Usually, however, state Commissions grant firms the choice between adhering to an incentive

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[36] See Appendix 4 for a survey of the states' experience with the deregulation of competitive services.

scheme or to continue under rate of return regulation. Thus, the existence of an incentive regulation scheme in the state implies a change in the state Commission's attitude towards regulation. We measure that change by creating a dummy variable equal to 1 if there is a firm in the state with an earnings sharing scheme.

VI. EMPIRICAL RESULTS

We start this section by analyzing the role of the demographic and economic factors. We then present and analyze estimates for the partial adjustment and baseline growth models. Our results are consistent with the following themes: first, economic and demographic characteristics of local exchange territories strongly influence the level of infrastructure deployment; second, excluding economic and demographic characteristics from the analysis biases predictions about the effects of incentive regulation schemes; third, price regulation greatly increases LEC's incentives to deploy fiber optic cable, SS7 equipped switches, and ISDN lines; finally, earnings sharing schemes provide weaker, and potentially counterproductive, incentives for the deployment of digital infrastructure.

Preliminaries

In Table 1 we provide descriptive regressions of infrastructure levels on economic and demographic variables. Table 1 shows that economic and demographic variables are important in explaining the cross sectional variation of infrastructure deployment. Indeed, across the four columns of Table 1 we see that the variables affect deployment in the expected manner. For example, fiber and ISDN deployment are positively correlated with population in large cities

(Urbanized). On the other hand, the deployment of ISDN and SS7 falls the more concentrated the LECs customers are in small towns (Urban) Rural population, on the other hand, does not have a consistent impact across the four measures of infrastructure.

Hourly construction wage, a measure of cost, is negatively correlated with the deployment of fiber, ISDN and SS7 (but insignificantly so for SS7). Concerning income measures, FIRE (finance, insurance and real estate) income seems to be a main determinant of digital infrastructure deployment, as it is positively and significantly correlated with the deployment of all infrastructure measures except ISDN. On the other hand, average per capita income in the LECs territory is positively correlated only with the deployment of ISDN, and the extent of manufacturing income in the LEC's territory is only significant in the deployment of fiber optic cable. The regional Bell operating companies seem to deploy more digital infrastructure than the other holding companies, except as it relates to switches.[37] While this result may reflect firm specific conduct, it may also reflect that RBOCs are located in areas with higher than average demand for high quality services. Firm specific effects will be dealt with when considering the determinants of growth rather than levels.

Finally, Table 1 shows that holding constant demographic and economic characteristics, the different measures of infrastructure have been growing at different speeds. ISDN and SS7 seem to have parallel growths, having annual growth rates of roughly 100%. ISDN and SS7 seem

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[37] Since information on SS7, ISDN and DSPC switches is available only for Bell and GTE LECs, in the estimation of the determinants of these measures we include only a dummy for Bell operating companies

to be at the same stage of diffusion as fiber was in 1987/1988. DSPC switches, on the other hand, have a slow growth rate, with only 1991 showing any substantial growth over 1989. To summarize, Table 1 suggests the economic and demographic characteristics of the LEC territories are important determinants of digital infrastructure deployment.

Partial Adjustment Model

We estimate the partial adjustment model (4) for fiber optic cable deployment for the period 1987-1991.[38] The empirical specification used in (4) involves all the regulatory and economic variables described in the previous section. We also create two interactions. First, because the effect of the incentive regulation could depend on the LEC's initial deployment conditions, we interact price cap and price freezes on the LEC's 1986 level of fiber deployment.[39] That is, we let the effect of price cap and price freezes vary, in principle, across LECs. A second set of interactions relate to the hypothesis that the effect of price regulation depends on whether it is coupled with an earnings sharing scheme. Thus, we create two interaction terms, one for price cap and earnings sharing, and another for price freeze and earnings sharing.

Table 2 reports four sets of results. The first two columns report the estimated values for the regulatory coefficients when demographic and economic variables are excluded. The third

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[38] Because a potentially serially correlated lagged dependent variable is included in (4), the equation has to be estimated by instrumental variables techniques. Furthermore, the use of a lagged dependent variable implies losing one year (101 observations) of information.

[39] Because of the potential for correlation between the 1986 levels and the errors in further years, we treat the 1986 level as endogenous.

and fourth columns report the estimates when demographic and economic variables are included.[40] We observe, first, that the inclusion of demographic and economic variables has a large impact on the estimated parameters of the regulatory variables. Thus, attempts to explain determinants of fiber optic deployment without consideration of LEC specific economic and demographic considerations will provide biased predictions on the effects of incentive regulation schemes. The second and fourth column impose the constraint that price cap and price freezes have similar effects on fiber deployment. Again, we find that the exclusion of demographic and economic variables drastically affects the predicted effects of incentive regulation. For example, in both sets of estimates the inclusion of LEC specific demographic and economic variables reduces by almost half the impact of each of the price cap regulation variables.

Focusing now on columns 3 and 4 we find that the larger the LEC's initial deployment of fiber optic cable, the smaller the predicted effect of imposing price cap regulation.[41] Furthermore, imposing both price caps and earnings sharing seems to have a detrimental effect. Although not very precisely estimated, it wipes out any advantages inherent to either price cap or earnings sharing. While the effect of price freezes is positive (particularly for LECs with at least a minimal fiber deployed in 1986), it is also not precisely estimated, except that the combination of price freeze and earnings sharing is, again, negative and both statistically and economically significant. In contrast to the effect of price regulation, earnings sharing alone does not seem to be associated

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[40] To simplify the exposition, the estimated coefficients on the demographic variables are omitted from the Table.

[41] The average 1986 fiber deployment (in logs) was 4.55

with increased deployment of fiber optic cable once LEC specific demographic features are taken into account.[42]

Column 4 provides the estimates for the same partial adjustment model imposing the constraint that price cap regulation and price stabilization schemes have similar effects on fiber deployment. That is, we explore here the implications of price regulation in general, without separating between price cap and price freezes. Thus, columns 2 and 4 report the same coefficients for variables involving price cap as for those involving price freezes. Although the coefficient of price regulation now is smaller than that of price cap in column 3, it is still quite large and economically meaningful. The coefficient of the interaction of price regulation and initial deployment levels is negative but small and not statistically significant. On the other hand, the coefficient of the interaction of price regulation and earnings sharing is negative, and although it has large standard errors, its point estimate is large and economically meaningful. In both columns 3 and 4 the adjustment process coefficient is approximately .5, suggesting a relatively slow adjustment process.

Overall, columns 3 and 4 provide a very similar economic picture. Price regulation improves incentives to deploy fiber optic cable. Price cap regulation has a stronger effect than price stabilization schemes. The effect of price regulation falls with the LEC's initial levels of fiber optic deployment. Earnings sharing schemes, by themselves, seem to trigger some more fiber

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[42] Recall that to obtain the long run effect of a regulatory change we have to divide the estimated coefficient by the adjustment factor α

deployment, although their effect is not statistically significant. Combining earnings sharing schemes with price regulation, however, seems to eliminate the extra incentives to deploy fiber optic cable. These results question the advantage of using earnings sharing schemes. Finally, Table 2 suggests that there may not be much difference between price cap and price freezes in promoting fiber optic deployment. Indeed, the explanatory power of columns 3 and 4 is almost the same. The difference is statistically insignificant when we take into account that the restricted model has three less explanatory variables.

To provide a summary statistic on the relative effect of incentive schemes we computed the expected increase in long run fiber deployment for those LECs that as of 1991 were not subject to any incentive regulation whatsoever.[43] Table 3 column 1 reports the predictions from using the estimated parameters from the unrestricted model in Table 2 column 3, while column 2 uses the estimated parameters reported in Table 2 column 4.

Looking at the second column of the table we find that, on average, subjecting those LECs to price cap regulation only would have increased their long run deployment of fiber optic cable by 100%, subjecting them to a price freeze only would have increased their long run

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[43] We compute the expected change in long run fiber deployment as follows. Let the portion of $X\beta$ dealing with incentive regulation given by β_1PriceCap + β_2PriceCap*Fiber$_{86}$ + β_3PriceCap*Earnings sharing + β_4PriceFreeze + β_5PriceFreeze*Fiber$_{86}$ + β_6PriceFreeze*Earnings sharing + β_7Earnings sharing. The effect of only imposing price caps on a LEC currently subject to no incentive scheme regulation, is given by $(\beta_1 + \beta_2 \text{Fiber}_{86})/\alpha$, where α is the partial adjustment coefficient. The effect of simultaneously imposing price cap regulation and an earnings sharing scheme would be given by $(\beta_1 + \beta_2 \text{Fiber}_{86} + \beta_3 + \beta_7)/\alpha$. The effects of implementing price stabilization plans can be derived analogously. The effects of implementing only an earnings sharing scheme is given by the coefficient of earnings sharing (divided by α).