Modern Telecommunications Infrastructure and Economic Activity: An Empirical Investigation

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This study focuses on the impact of telecommunication infrastructure on economic activity in two sectors: fire, insurance and real estate; and manufacturing. Results indicate that modernization of the telephone network is associated with more fire, insurance and real estate activity in the local region, while it is not associated with more manufacturing. Once other determinants of growth are controlled for, a doubling of fiber optic cable leads to at least a 10%, and possibly a much higher, increase in the level of economic activity in fire, insurance and real estate. This result implies that the level of modernization of a telecommunications network has an economically important influence on the amount of high tech white collar activity in a region, while it is less important for manufacturing activity, which typically employs less modern telecommunications services.

1. *Introduction*

That improvements to infrastructure lead to more economic activity is not a controversial statement, whether in a developing country or in a complex and developed market economy. The magnitude of the gains from infrastructure investment or modernization, however, are unknown. This is so because it is difficult to measure the direct and indirect impact of better infrastructure on economic activity and growth. Infrastructure improvements reduce the costs and increase the quality of economic activity in infrastructure-intensive sectors. In turn, improvements in one infrastructure-using sector beget improvements in others, thus multiplying the indirect effects. The benefits may accrue to regions where the infrastructure is located but may also spread to nearby regions. Connections between

Industrial and Corporate Change Volume 4 Number 4 1995

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economic sectors are difficult to trace, and the quality and quantity of infrastructure are notoriously difficult to measure. Furthermore, since new investments take advantage of new opportunities linked to new infrastructure only slowly, the economic effects of infrastructure improvements have long lags. Finally, some sectors of the economy benefit directly more than others, while other sectors benefit indirectly. Thus, aggregate data do not isolate different experiences in affected and unaffected sectors.

In this study we attempt to avoid many of the difficulties encountered in previous research. We focus on only one type of infrastructure, telecommunications, and carefully measure its impact. From a statistical standpoint this is an ideal 'natural experiment', i.e. there is large variation in the quality of local telephone networks across the USA, particularly in the level of modernization. More important, there is also considerable debate today about the economic merits of modernizing the network to the technical frontier allowed by digital technologies. These issues have received special attention in light of the publicity surrounding the much-anticipated 'information superhighway'. Clearly local telephone networks will be a crucial part of that highway, but their exact role still remains sketchy.

We focus on the impact of telecommunication infrastructure on economic activity in two sectors: (i) fire, insurance and real estate (hereafter FIRE) and (ii) manufacturing. This focus has several advantages. First, FIRE is a growing information-intensive sector, and its growth is sensitive to the availability of modern telecommunication services used in conjunction with advanced computing technology. We interpret FIRE's growth broadly as a measure of the amount of technically advanced information-intensive white collar activity in a region. Telecommunications network quality should strongly influence the amount of this type of activity by reducing the costs of transacting, and by improving the variety and quality of services information-intensive business can provide. Second, measurement problems are held to a minimum, since geographic variation in the quality of networks should lead to related (and localized) geographic variation in the quality and amount of white collar work. Third, manufacturing offers an interesting contrast to FIRE. While some manufacturing is information-intensive and some is not, much information-automation of factory floors is internal to firms and does not use the most modern features of a local telecommunications infrastructure as heavily. As a consequence, manufacturing should be less sensitive than FIRE to the modernization of the local telephone network.

We use the amount of fiber optic cable deployed as a proxy for the extent of modernization in a local telecommunications network. It positively correlates with the adoption of digital technology and modern services that use digital technology. This leads us to choose a novel region for comparative analysis: the service territories of local exchange companies at the sub-state level. This is more dissagregate than any previous cross-state comparison of infrastructure of telecommunication investment. It has the advantage that it highlights differences in network quality at a sub-state regional level, which is important if network modernization differences relate to inter-phone company differences in quality. Finally, our research differs from previous work in our econometric treatment of these issues; we treat modern infrastructure as endogenous, and we offer an expanded list of 'controls' (i.e. regressors) for the causes of sectorial activity and growth.

Our results show that, controlling for other effects, the modernization of the telephone network is associated with more FIRE activity in the local region, while it is not associated with more manufacturing. We find that, once other determinants of growth are controlled for, a doubling of fiber optic cable leads to at least a 10%, and possibly a much higher, increase in the level of economic activity in FIRE. This relationship persists in all specifications and samples. We broadly interpret this result to mean that the level of modernization of a telecommunications network has an economically important influence on the amount of high tech white collar activity in a region while it is less important for manufacturing activity, which, typically, employs less modern telecommunication services.

We first put our experiment in context with a review of recent literature related to our topic. We follow with a discussion of our econometric methodology and data. We finish with a discussion of our results.

2. *The Infrastructure/Growth Relationship*

There is an extensive literature on the economic consequences of infrastructure investment in modern market economies (for a review see Munell, 1992), where infrastructure is broadly defined. There is also a comparatively more modest and specialized literature on the relationship between telecommunications and economic growth and activity. Most of these studies, however, are aimed at understanding developing economies, not technically advanced market economies.[1] Our purpose here is to briefly review the main findings of the statistical studies examining the impact of telecommunications in developed countries, outline their research framework and put our own study in the proper context. This will highlight how our methodology departs from the extant literature.

Let us first discuss recent studies of the returns from infrastructure investment, where infrastructure capital is broadly construed to be highways,

[1] See Mueller (1993) for a 'skeptical' review. Also see Roller and Waverman (1994).

water and sewer systems, schools, hospitals, electrical and transportation facilities, and other publicly owned equipment and structures. As a starting point, everyone agrees that public capital investment can and does expand productive capacity of an area in the long run, by both increasing resources and expanding the productivity of existing resources (Aschauer, 1990; Congressional Budget Office, 1991; Munell, 1992). It is also widely acknowledged that the important long-term effects are those usually associated with technological advance because innovation confers benefits to both suppliers and users. If users do not have to fully pay for improvements to roads or advances to telecommunications networks or any other public investments—either because competition reduces the prices for these services or regulation brings prices down to marginal or average costs rather than at monopoly levels—then the gains to users can potentially be quite large (Aschauer, 1990).

Broadly speaking, the evidence from many empirical studies is that investment in public infrastructure provides immediate economic stimulus, and also has a significant, positive effect on long-term output and growth (Congressional Budget Office, 1991). Most of the open debate concerns the strength of these relationships and interpretation of any estimates. Munell's survey of production function estimates of the returns from public capital shows that all estimates of infrastructure investment are positive, but they range greatly. Point estimates of output elasticities from infrastructure capital start as low as 0.03 and range as high as 0.39 (Munell, 1992, p. 194). These estimates depend on the level of aggregation (e.g. across metropolitan areas, states or nations), specification of the model (e.g. Cobb–Douglas, translog) and years examined. Some authors (Aschauer, 1990) have argued (from examining the higher estimates) that the returns are higher to investment in public infrastructure than their private sector counterparts, implying that further government investment is warranted. Others have criticized many features of the estimation framework, or found reasons to come to a less certain policy recommendation.

Criticism takes several forms [see Munell (1992) and references therein for a review of many potential flaws]. First, some critics argue that there is a spurious correlation between public investment and economic activity over time, requiring special econometric treatment (i.e. first-differencing), which generally diminishes or eliminates any large effects from infrastructure investment. There is no agreement, however, on the merits of this correction. Critics argue that it is necessary and sufficient, while others argue that it is differencing out all the interesting economic phenomena. Second, the range of estimates leads many critics to be skeptical of all estimates. This is probably an unfair criticism because some patterns seem to persist in the results. All estimates are positive and the smaller estimates tend to occur in studies that focus on smaller geographic units, where spillovers from local investment are likely to be larger and geographically focused returns smaller. The criticism, however, is partially on target in that many estimates lack precision or are difficult to associate with any concrete infrastructure investment program, which makes them rather difficult to use in defense of a specific policy proposal. Third, standard statistical methods assume that causality runs only from infrastructure to economic activity, which does not correct for dynamic feedbacks, i.e. more growth may lead to increased demand for all public investment, which, in turn, leads to more growth and so on. If another unobserved factor causes either infrastructure or economic activity or both to increase, then these standard methods assign too much of the responsibility for growth to infrastructure deployment.

One potential partial answer to these issues is to eschew aggregate analysis and focus instead on the impact of a single type of infrastructure investment, which is the strategy of several studies on the economic effects of investment in telecommunications (and also of this paper). Here we focus only on recent studies of the influence of modernization of telecommunications networks on growth in modern developed economies. In particular, we ask whether variation in degree of modernization across regions of the USA influences economic activity in those regions (US Department of Commerce, 1991). There has been surprisingly little research done on this particular topic, though related issues have received considerable attention outside the US context.[2]

One reason why this topic received little academic attention is because the US telephone system is rather unusual in a global context. The existing US telephone system is already largely ubiquitous and functional in virtually all residences and business. Every study agrees that the absence of last-generation modern telephone functionality, e.g. the absence of touch-tone service or the presence of multiparty lines, handicaps the conduct of business (Mueller, 1993). Such handicaps can act as a bottleneck or barrier to private activity, particularly in developing economies, and influence business location decisions. Unfortunately, whether it is possible or worthwhile to generate additional economic activity as a result of modernizing a telephone system to the technical frontier is still unresolved. What are the cost and benefits

[2] There is comparatively much more on the influence of telecommunications infrastructure investment on developing and rural economies. However, this literature is usually concerned with issues distant from the present topic, such as the level of penetration rates and quality of basic service. For example, see Hardy (1980) or Saunders *et al.* (1983). Reviews of earlier work in telecommunication are usually about modernizing the post-WWII US telephone system (see, for example, Mueller, 1993). See also Roller and Waverman (1994).

of upgrading from a merely functional to a state-of-the-art digital system capable of carrying many additional services?

Dholakia and Harlam (1944) examined this issue by taking advantage of variations in telecommunications quality across the fifty states. Using panel data techniques, they found a positive relationship between investment in telecommunications, as represented by investment in business access lines, and economic activity, as represented by average annual pay or per capita income. This relationship persists even when controlling for other factors such as education of the state populace, energy consumption and other less important inputs to the local economy: However, the estimated relationship varies considerably from specification to specification and from one model to the other. It is difficult to interpret their estimates in light of different estimates using different specifications. The exercise is in the right framework, but within-state variation may overwhelm cross-state variation, thus making these statistical tests difficult to perform. Although the answer seems to be positive, it is unclear how much modernization is enough.

In a recent large study, DRI used an input/output approach to measure the contribution of telecommunications to economic efficiency, in particular, improvements in sectoral total factor productivity. They performed the following conceptual experiment: if the level of telecommunications investment stayed constant after 1963, how much worse off would the economy be in 1982? As summarized in Cronin *et al.* (1993b), DRI estimated that there would be a $46.5 billion dollar resource saving (in 1990 dollars) due to increased efficiency in the supply of telecom equipment and service. Using 33 years of aggregate US data and standard production function approaches, they found that about 25% of productivity growth over the late 1970s to 1990s was attributable to improvements in telecommunications productivity and consumption efficiencies (substituting into cheaper telecommunications services). These effects were especially pronounced in finance, transportation, trade, real estate and petroleum refining. Cronin *et al.* (1993a) performed a similar analysis for a much more dissagregate sample, a cross-section of counties in Pennsylvania, and confirmed the findings made with more aggregate data.

While this estimate relies on a questionable conceptual experiment (in light of the large dynamic changes in the US economy and difficulties in measuring productivity) and has come under severe criticism as a result of its strong policy recommendations, it nonetheless suggests that the ballpark for estimated savings is quite large. Still, a number of other lessons arise from this research. First, while the Cronin studies were careful not to assume that causality runs only from infrastructure to economic activity, they did not estimate structural models that account for dynamic feedbacks, preferring a reduced form approach. This suggests that controlling for statistical endogeniety should be an important feature of any productivity analysis. Finally, there is significant room for more dissagregate analysis, either expanding beyond counties in a single state (e.g. more than Pennsylvania) or below a cross-state level of comparison. Spillovers from local telecommunications investment are likely to be larger and less geographically focused for economic activity that is not geographically focused.

We are sensitive to these methodological concerns. First, we adopt a framework that has elements of dynamic change embedded in it, albeit in a simple structural model. Second, our econometric framework controls for statistical endogeneity. Third, we compare across sectors and test our hypotheses about the importance of telecommunications in different sectors. Fourth, we use a very dissagregate analysis, below the state level, but contrast infrastructure across many different regions, taking advantage of the natural experiment embedded in cross-regional differences in telecommunications network quality.

3. *The Econometric Framework*

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

$$Y_{kjt} = X_{kjt}\beta + \varepsilon_{kjt}, \tag{1}$$

where Y reflects the actual level of FIRE or manufacturing in the territory of the local exchange company k in state j at time period t, and X reflects a matrix of explanatory variables, such as infrastructure, market (demand) and cost conditions, which also differ across local exchange companies, states and time period. ε is usually assumed to be an iid error term. With the addition of time dummies, (1) assumes that the same cross-sectional relationship holds over time. The equation, however, may be inappropriate when dealing with rapidly growing infrastructure deployment and growing economic activity, where the implicit assumption of long run equilibrium does not hold. In these circumstances, it becomes more interesting to attempt to explain the extent of differential infrastructure growth across regions.

To analyze the determinants of differential growth we take a related statistical approach. With relatively long time series it is possible to attempt to estimate an investment adjustment model. Investment adjustment models assume that the current level of an activity is a weighted average of its long run desired level (given demand and supply considerations) and of its lagged level, 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 level of FIRE or manufacturing activity in firm *j*'s territory in state *k* in time period *t*. Furthermore, let Y^*_{kjt} be given by

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

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 $\upsilon_{kjt} = \alpha\varepsilon_{kjt} + \mu_{kjt}$.

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 activity 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 infrastructure and economic variables on the long run desired stock level of FIRE.

An inspection of (4) makes clear, without sufficient time series variation per region in Y_{kjt} and X_{kjt}, it may not be feasible to separate the contribution of the lagged dependent variable from that of the current 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. In this respect, a main limitation is that fiber optic cable information per local exchange carrier (LEC) is available only from 1986 on. Moreover, one may expect long adjustments of FIRE and manufacturing to infrastructure deployment, because of technological uncertainties, sunk costs or other more mundane rigidities.[3]

Finally, in our estimations we assume that the level of fiber, wages and price of telecommunications services, and Y_{kjt-1} are statistically endogenous. We instrument for these variables with local regulatory policies influencing local exchange companies, which we assume are statistically exogenous to

[3] See Rosenberg (1982) on the resolution of technological expectations and Dixit and Pindyk (1994) on investment with sunk costs.

TABLE 1.

	Mean	SD	Minimum	Maximum
Log of FIRE	13.02	1.90	7.50	17.55
Log of manu	14.39	1.81	6.90	18.02
Log of fiber	8.45	2.88	0.00	13.02
Log of per capita inc	9.59	0.15	9.23	10.04
Log population	6.85	1.48	2.04	10.17
Frac urbanized pop	0.44	0.28	0.00	1.00
Frac urban pop	0.17	0.12	0.00	0.73
State econ growth	1.48	3.11	−11.43	11.04
Frac of empt in st	0.43	0.35	0.001	1.00
Log FIRE wage	2.39	0.17	2.12	3.14
Log manu wage	2.44	0.14	2.08	2.87
Log FIRE emp	10.36	1.68	5.70	14.09
Log manu emp	11.11	1.72	4.02	14.55
Log Connech Ch[a]	1.89	0.41	0.74	2.68
Log three min[a]	−2.43	0.71	−3.89	−0.46

Results are from 606 observations except [a] 365 observations.

the level of Y_{kjt} but not X_{kjt}. This, however, does not mean that regulatory policies are naturally random. The regulator's preferences and the nature of the state's political institutions will determine whether a new regulatory policy will take place or not.[4] In other words, behavioral endogeneity is not inconsistent with statistical exogeneity in our econometric framework.

4. *Data*

We undertook our analysis at the local exchange company level for the reasons explained below. We used two main sources of information. For local exchange company specific information and data on state regulations we used the data developed by Greenstein McMaster and Spiller (GMS; Greenstein *et al.*, 1995). Summary statistics are presented in Table 1.

GMS gathered demographic characteristics for each of the LEC's territories in each state for the period since divestiture. Because demographic information is available until 1992, and most of the relevant digital infrastructure data start to be reported in 1986, our current dataset covers the period 1986–1992. GMS also gathered infrastructure 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).

[4] See, for example, Donald and Sappington (1995) for an analysis of the behavioral endogeneity of regulatory policies, and Smart (1994) for an analysis of the role of political institutions on the determination of telecommunications regulatory policy.

There are 101 local exchange carriers in each year of the GMS data,[5] which results in a dataset of 606 observations. 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.[6] The county data were then aggregated to the company level within each state.[7] The main source of the demographic (county level) data was 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

We use two variables: Log of MANU INCOME and log of FIRE INCOME. FIRE INCOME represents total real sales or revenue for the financial, insurance and real estate sectors for the territory served by the LEC in that state.[8] MANU INCOME represents the value of manufacturing production for the territory served by the LEC in a state.[9]

We chose these two sectors for several reasons. First, FIRE has been one of the most dynamic sectors in the US economy. Much of that growth is attributed to the development and adoption of data-intensive computing technology, which is technically compatible with modern telecommunications technology. Second, the market-boundary definitions for FIRE did not radically change with the 1987 revisions of the Standard Industrial Classifications.[10] Therefore, while FIRE is clearly not the only information-intensive sector in the US economy using modern telecommunications, its boundaries are easiest to define over time—unlike many other markets associated with electronics or computing services. Third, FIRE includes many activities with relatively concentrated geographic scope, such as banking and credit activity. Hence, local FIRE activity will be most sensitive to local telecommunications features, if it is sensitive at all. Fourth, several other information-intensive sectors could not serve as similar proxies. For

[5] Only companies that earn over $100 million in revenue are required to report to the FCC.

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

[7] 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.

[8] This includes all economic activity in Standard Industrial Classifications (SIC) codes 60–67 under both the 1972 and 1987 SIC code definitions.

[9] This includes all economic activity for durable and non-durable goods which falls under the SICs 20–26 and 31–39.

[10] Those revisions were largely responding to the dramatic economic changes brought about by technological developments in electronics and electronic-using sectors.

example, rail, trucking and air transportation, as well as some wholesaling and retailing operations, frequently use private (and often modern) communications networks. Hence, they are less likely to be sensitive to the modernization of the (public) local telephone company's infrastructure. Fifth, generally speaking, much factory automation is information-intensive, but it is internal to firms and does not use the most modern features of a local telecommunications infrastructure as heavily.[11] Hence, MANU offers an interesting contrast since it typically employs modern local telecommunications less intensively.[12] In sum, we interpret FIRE broadly as a measure of the extent of high technology and data-intensive white collar activity in a region, while MANU represents the extent of blue collar activity.

Modern Infrastructure Variables

We use log FIBER as our measure of infrastructure deployment. This is fiber optic deployment at the company level for each firm in each state. Log FIBER is defined as the total miles of fiber optic cable deployed by the company within its service territory in the state.[13] Fiber optic cable allows for high speed transfer of voice, video and data transmissions.[14] We interpret this variable as a measure of the extent of modernization of the local telecommunications network in a local region, and treat it as statistically endogenous.

Other Telecommunications Network Variables

In some specifications we include the price of telecommunications services. As a measure of the price of access, we use the monthly (regulated) price of connection for a residential customer. An average business rate is clearly preferable, but more difficult to collect due to widespread discounting. For the price of long-distance phone service, we use the cost of a three minute

[11] An important exception in this time period is associated with the development and adoption of inventory methods that rely on quickly coordinating geographically dispersed suppliers and distributors. These methods often require modern computing facilities and modern telecommunications services. However, their impact does not tend to be as geographically concentrated, so we do not expect them to influence our results.

[12] There are some easily identified exceptions to this generalization, particularly in publishing, which we excluded from our measure of manufacturing activity, scientific and medical instruments, and electronic and office equipment, which we have included. However, we expect the exceptions to be overwhelmed by the majority.

[13] 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).

[14] 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 is measured in fiber miles.

call of a ten mile distance.[15] As it turned out, both of these data were difficult to collect and only available for 365 observations of LECs in our sample.[16] Thus, we estimate our models with and without these variables. When they are included, they are treated as statistically endogenous.

Other Exogenous Variables: Economic and Demographic Data

The demographic data were collected at the state and county level for the continental USA, including the District of Columbia. The GMS demographic dataset includes numerous variables that help characterize each area being served by the local exchange carrier. In the collection of these variables, emphasis was placed on identifying factors related to the local economy, which influences the demand for, and costs of, activity related to FIRE and manufacturing.

Population and income are two features of the service territory of the LEC which have an impact on the demand for such infrastructure. We use three measures of population. POPULATION represents the total population that lives in the territory served by the company. This is a measure of the scale of demand for FIRE. At the same time it reflects the availability of labor in the region, thus affecting the plant location decisions by manufacturing firms. URBANIZED POP represents the fraction of the population served by the company that lives in cities with populations 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 be associated with more white collar work, increasing the potential benefits from digital infrastructure. URBAN POP represents the fraction of the population served by the company that lives in cities with populations of more than 5,000 but less than 50,000. URBAN POP should have a smaller impact than URBANIZED POP. The omitted fraction is for rural settlements comprising populations of less than 5,000. The smaller the fraction of population that is rural in the LEC territory (holding constant total POPULATION) the higher the probability that most of its population is located in a metropolitan area.[17]

Log AVG PER CAP INC represents the log of the real average per capita

[15] Often this means that we use the published price for a call within an interval, such as 8–15 miles. Since discounts from published rates have increased over time, the year dummies will pick up any discrepancies between published and average paid prices.

[16] The smaller sample arises from our inability to obtain full historical records from all independent LECs or their regulators.

[17] Although higher economic growth may lead to population increases (particularly in urban settings), it is reasonable to look at population as exogenous since the sectors under consideration are a small fraction of total economic activity.

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 potential demand for FIRE. At the same time, it may reflect quality of life differentials, hence affecting the location decision of manufacturing firms. FEMPL is the fraction of employment in the state found in the region. This variable signals the economic importance of the region in the state. Higher fractions should lead to larger demands for services. SGDPGROW measures the growth rate of GDP within the state. This tells us about improvements in general economic conditions state-wide and other macroeconomic effects that influence local economies. Finally, we also include the log of the average wages and employment for FIRE or manufacturing in the local region, depending on the endogenous variable we used. When wages and employment are included, they are treated as statistically endogenous.

Instruments: the State Regulatory Environment

We instrument for the quality and price of telecommunications with measures of the state regulatory environment (as well as other exogenous variables). These are good instruments since they should influence the telecommunications network, but should, in principle, be uncorrelated with contemporaneous errors in predicting levels of FIRE or MANU.

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,[18] 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 its authority, and to what extent it does 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. Since a complete picture of the regulatory environment cannot be determined from any one policy variable, we consider policies that differ substantially across states.

[18] 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 1991 year effect.

The following set of general regulatory variables is used in the study: (i) unrestricted bypass; (ii) entry of competitive access providers; (iii) resale of local exchange services; (iv) intraLATA competition; and (v) deregulation of competitive services in the state. These variables take a value of 1 if the state Commission has taken a positive policy concerning that regulatory issue. These are defined in detail in GMS.

Incentive regulation is the another key component of the regulatory environment faced by the LECs. Incentive regulation varies drastically across companies, even within a given state. GMS created three non-exclusive types of incentive regulation variables: price caps, price freezes and earnings sharing.[19] For a LEC's 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. 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.[20] For a regulatory structure to be categorized as EARNINGS SHARING the profitability of the LEC must be neither totally capped nor totally unregulated.[21] As discussed above, other states have introduced more restrictive sharing arrangements.

5. *Results*

Tables 2 and 3 present the results of estimating (1) and the adjustment model in (4) respectively. Each table presents results from using the log of FIRE or the log of manufacturing as the endogenous variable. In addition, each specification includes an estimate with and without the pricing variables. These tables support the conclusion that a more modern local telephone system leads to more white collar work in a region, but not necessarily to more blue collar activities. We summarize the results of (1) in Table 2 and then concentrate out discussion on the result of (4) in Table 3.

Table 2 shows that many factors determine regional differences in FIRE and manufacturing levels. The simple pooled cross-section time series specifications perform quite well, describing 98% of the variances in the FIRE

[19] Although price cap and price freeze are mutually exclusive, companies may be subject to both price regulation and earnings sharing schemes.

[20] For example, Southwestern Bell of Kansas had its basic residential and business rates frozen until 1995, independent of both actual costs and actual earnings. As the appendices to GMS make clear, however, most incentive regulation schemes are not independent of costs or profits, but rather call for continuous monitoring of profitability.

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

TABLE 2.

Endogenous variable	Log of FIRE	Log of FIRE	Log of manufacturing	Log of manufacturing
Constant	−2.3	0.53	0.51	0.13
	(1.6)	(2.3)	(0.50)	(0.64)
Log fiber	0.10**	0.20**	−0.017	0.003
	(0.01)	(0.03)	(0.011)	(0.017)
Log per capita income	0.44**	−0.02	0.05	0.05
	(0.22)	(0.34)	(0.06)	(0.09)
Log wage in FIRE/manufact	0.43**	1.08**	0.68**	0.93**
	(0.11)	(0.23)	(0.08)	(0.12)
Log employ in FIRE/manufact	0.95**	0.91**	1.09**	1.05**
	(0.12)	(0.19)	(0.26)	(0.04)
Log total population	−0.04	−0.09	−0.11**	−0.10*
	(0.12)	(0.18)	(0.02)	(0.05)
Fraction urbanized pop	−0.12	−0.21*	0.43**	0.33**
	(0.08)	(0.13)	(0.05)	(0.08)
Fraction urban pop	−0.74**	−0.70**	0.47**	0.45**
	(0.10)	(0.21)	(0.07)	(0.15)
State economic growth	−0.0068*	0.00	−0.0045*	−0.0055**
	(0.0037)	(0.00)	(0.0023)	(0.0027)
Fraction of emp in state	0.15**	0.14**	0.16**	0.10**
	(0.05)	(0.07)	(0.02)	(0.03)
Local connect charge	—	0.09**	—	0.05**
		(0.03)		(0.02)
Three-min local toll call	—	−0.003	—	0.00
		(0.02)		(0.01)
Number obs	606	365	606	365
R^2	0.986	0.983	0.995	0.993
Sum of squares	29.44	20.83	9.50	5.65

Year dummies not reported.
**T*-statistic > 1.64.
***T*-statistic > 1.96.

equations and 99% in the manufacturing equations. The high values of R^2 are not surprising in light of the number of reasonably good controls for cross-LEC differences in the scale of economic activity (e.g. employment and total population).

As for the telecommunications variables, as expected, fiber deployment helps to predict cross-sectional differences in FIRE but not in manufacturing. A doubling of the amount of FIBER leads to a 10% increase in FIRE in column 1 and 20% increase in column 2. It indicates that higher quality telecommunications leads to more white collar activity within the region. The differences between manufacturing and FIRE are not surprising, though. FIRE is highly information-intensive while manufacturing is not.

Interestingly, higher connection charges lead to more FIRE and manufacturing activity. This may be partially due to errors in variables. While lower telephone prices may trigger more telephone usage, higher monthly charges may also stand in for cross-sectional differences in (costly) telephone service quality or a larger local calling area. The cost of the local long distance call has no measurable effect on economic activity.[22]

The economic and demographic control variables help explain the amount of FIRE and manufacturing, but not always in the predicted direction. Wages and employment are both good predictors, not surprisingly. The positive coefficient on wages probably represents cross-sectional unobserved differences in the quality of labor across regions, i.e. higher quality labor is paid higher wages in different parts of the country. The elasticity on employment is close to one for both FIRE and manufacturing, as expected. The remaining demographic controls are more difficult to interpret. The fraction of employment in the state is positive and significant, as expected, but the remaining variables take the expected signs in the case of manufacturing but not for the FIRE equations. More rural regions have less manufacturing, though not necessarily less FIRE. Economic growth in the state, holding constant the LEC's territory specific economic conditions, seems to reduce the levels of both FIRE and manufacturing. However, the magnitude of the coefficient is quantitatively small.

Table 3 controls for previous levels of FIRE and manufacturing in our adjustment model. Recall that each of the estimated coefficients can be interpreted as $\alpha' = 1 - \alpha$, and $\beta' = \alpha\beta$ in the adjustment model. The estimates of 0.921 and 0.945 in the FIRE equations and 0.912 and 1.02 in the manufacturing equations indicate that adjustment is quite slow in both cases, the last result indicating that the model is not performing well at all. For example, in the simplest interpretation of the estimates for FIRE, a region would take over 5 years to achieve roughly half of the transition to larger output levels associated with higher levels of exogenous variables.[23] Also note that since $\beta = \beta'/\alpha$, the long run effects of the exogenous variables is much larger than a careless reading of β' initially indicate.

Now we concentrate on the results for FIRE. In both estimates the estimated coefficient of fiber is large and statistically significant. In both cases, the estimates show that a doubling of the amount of fiber increases the amount of FIRE by at least 14% in the local region in the long run. For column 1 the effect is 13.9% (1.1/.079), and for column 2, 45.45% (2.5/.055).

[22] A number of other specifications for the cost of a long distance call, either over a longer distance or a greater length of time, did not yield different results. In all cases, the coefficients were insignificant.

[23] This parallels the findings of Cronin *et al.*, (1993a) that the adjustment of productivity to telecommunications investment has long lags and is also quite slow, often taking at least a decade or more to achieve most of its impact on productivity.

TABLE 3.

Endogenous variable	Log of FIRE	Log of FIRE	Log of manufacturing	Log of manufacturing
Constant	−0.79	−0.04	−0.10	0.22
	(0.48)	(0.62)	(0.20)	(0.17)
Log fiber	0.011*	0.025**	−0.0083	−0.0013
	(0.006)	(0.01)	(0.0046)	(0.005)
Log per capita	0.13**	0.04	0.050*	−0.02
income	(0.07)	(0.08)	(0.02)	(0.02)
Log wage in	0.03	0.11	−0.02	0.04
FIRE/manufact	(0.03)	(0.07)	(0.05)	(0.05)
Log employ in	−0.01	−0.02	0.08*	−0.02
FIRE/manufact	(0.06)	(0.06)	(0.05)	(0.04)
Log total	0.08**	0.05	0.003	−0.0043
population	(0.03)	(0.04)	(0.012)	(0.01)
Fraction	−0.00	−0.02	0.01	0.06**
urbanized pop	(0.02)	(0.03)	(0.02)	(0.02)
Fraction	−0.18**	−0.24**	−0.03	0.12**
urban pop	(0.04)	(0.05)	(0.04)	(0.04)
State economic	0.012**	0.012**	0.0031**	0.004**
growth	(0.002)	(0.001)	(0.0011)	(0.0008)
Fraction of emp	0.02	0.02	0.006	−0.01
in state	(0.02)	(0.02)	(0.01)	(0.01)
Local connect	—	−0.012	—	0.004
charge		(0.01)		(0.008)
Three-min local	—	−0.0013	—	−0.02
toll call		(0.005)		(0.03)
$1-\alpha$	0.921**	0.945**	0.912**	1.02**
	(0.04)	(0.04)	(0.04)	(0.04)
Number obs	606	365	606	365
R^2	0.988	0.988	0.999	0.999
Sum of squares	2.60	1.38	1.62	0.40

Year dummies not reported.
**T*-statistic > 1.64.
***T*-statistic > 1.96.

It is interesting to note that the telephone pricing variables did not predict differences in levels of FIRE. This is probably due to the lack of much change in telephone prices over time; thus, most of the cross-sectional differences in prices was controlled for by the lagged value of FIRE. Combined with the estimates in Table 2, we interpret all four coefficient estimates on FIBER as strong evidence that modernization of the telephone network has direct impact on the amount of modern technology intensive white collar activity in a local region.

Finishing with the two estimates for FIRE, the other economic and demographic variables do not perform remarkably well. This is probably due to the lack of much relative change in many of these variables over time; thus, most of the cross-sectional differences in population, wages and employment were controlled for by the lagged value of FIRE. Consistent with this view, the recent growth in economic activity in the state is a significant and important contributor to change in the amount of FIRE (above and beyond lagged values). So, if the state is growing, so too is the level of white collar activity. Observe, however, that since this result is not supported by Table 2, it should be interpreted cautiously.

The results for manufacturing have many important differences too. In both estimates the coefficient on fiber is either the wrong sign or small and statistically insignificant. We take this as evidence that modernization of the telephone network does not have as strong an impact on the amount of blue collar work in a local region as it does on white collar activity. The telephone pricing variables also do not predict differences in levels of manufacturing. Again, this is not so surprising, since manufacturing is not nearly so information intensive. We note, however, that the connection charge was significant in Table 2. Its importance in Table 2 for both manufacturing and FIRE but for neither in Table 3 is consistent with our view that it may stand in for unobserved cross-sectional differences in telecommunications quality that do not change over time. Finally, the other economic and demographic variables do not perform particularly well, except for the state economic growth variable. As expected, if the state is growing, so too is the level of manufacturing activity.

6. *Final Comments*

The effect we estimate here is clearly not the only effect of an improved telecommunications network. Our estimates do not account for spill-overs outside the region or outside the sectors studied. We have only examined activity within the FIRE and manufacturing sectors, thus ignoring sectors that may have strong linkages either upstream or downstream from FIRE and manufacturing. In particular, we have not examined the users of services from FIRE. We conclude that not only is the impact of a better telecommunications network on white collar activity potentially large, but once all spill-overs are accounted for, its effect is potentially much larger than what we have estimated here.

Acknowledgements

This research was funded, in part, by the Research Board and the Institute for Government and Public Affairs at the University of Illinois, and by the Ameritech Corp. through the Law and Economics Consulting Group. This paper was written while Greenstein was a Visiting Scholar at CEPR, Stanford and at the Institute of Management, Innovation and Organization, Haas School of Business, University of California, Berkeley. Their financial support is greatly appreciated. Susan McMaster provided able research assistance.

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