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Abstract

This paper examines the impact of institutional factors on the investment behavior of local operating companies in the U.S. telecommunications industry. In particular, the impact of the separations process which has been used to provide a local sector cross-subsidy, is evaluated but the impact of state-level pricing regulations which in the last decade has moved to incentive based schemes is also taken into account. Investment patterns in fiber optic and digital technology are studied for the period 1991 to 1993. The key results obtained are that the separations process, whereby a greater proportion of investments and costs are allocated to the federal regulatory jurisdiction, does have a positive impact on new technology investments. The introduction of price-cap regulation schemes also has a positive impact on new technology adoption, as expected. Where price-cap schemes are introduced in conjunction with a mixed earnings sharing scheme, or where only an earnings sharing scheme is introduced, then the impact on new technology investment turns out to be mixed.

Keywords. Separations; Incentive Regulation; Technology Adoption

JEL Classification. L 96 (Telecommunications); O 33 (Technological Change: Choices and Consequences)

INTRODUCTION

Within the framework of the theory of the firm three approaches have been mainly used to explain firms' investment behavior. The first focusses on the factor-saving bias in the use of scarce resources that technical change engenders (Hicks, 1932; Samuelson, 1965). The second focusses on the influence of demand growth on the rate of technical change (Griliches, 1957; Schmookler, 1966). Contemporary researchers have also established that firm-level factors are important explanators of firms' investment behavior (Davies, 1979; Ginsberg and Venkatraman, 1992; Karshenas and Stoneman, 1994; Majumdar, 1995). Concomitantly, institutional forces are recognized as important in shaping the behavior of firms, because the institutional framework defines the choice-sets that are available to firms for exploiting economic opportunities (DiMaggio and Powell, 1983; North, 1990). Yet, very little empirical literature exists which evaluates how institutional forces impact firms' technology investment behavior.

Institutions are the rules of society (Knight, 1952) which play an important role in establishing expectations about the outcomes with respect to resource usage in economic activities (Davis and North, 1971). Institutions define the economic and political environment within which firms operate and undertake their various activities, and by doing so govern the nature of income streams that can or ought to be generated with the use of resources, plus also the way assets are to partitioned (Hayami and Ruttan, 1985). Changes in institutional norms and rules may be brought about because of variety of reasons; these reasons have been extensively discussed by North (1990), Ostrom (1990), Thirtle and Ruttan (1987) and Tolbert and Zucker (1983). But once the institutional outcomes are in place, then these outcomes dictate the normative context within which firms operate and the resources that flow to or from it (Zald, 1978).

A number of researchers have attempted to capture the impact that institutional factors have on firm-level behavior. For example, Mezias (1992) examines the extent to which institutional factors influence the adoption of financial reporting practices among Fortune 200 companies. Nay (1991) examines the extent to which institutional factors help explain the outcome of bargaining concessions in the airline industry. Palmer, Jennings and Zhou (1993) assess the role that institutional forces play in explaining the diffusion of the multi-divisional organizational structure among large industrial corporations in the U.S. in the 1960s; and, Tolbert and Zucker (1983) analyze the role of institutional factors in helping the diffusion of early civil service reform in the United States. Other than a study by Zucker (1987) which evaluates the extent to which institutional factors influence the adoption of new technology within California hospitals in the 1959-1979 period, there is a surprising lack of evidence on the impact that institutional factors have on the extent of new technology investment by firms.

This paper examines how institutional forces, and in particular the nature of cross-subsidy, shape the investment behavior of local operating companies in the U.S. telecommunications industry. In the U.S telecommunications industry a primary institutional factor that significantly influences the behavior of firms is the separations mechanism. This mechanism, which determines how total local operating company costs and investments are allocated between state and federal regulatory jurisdictions for cost-recovery purposes, has historically served to cross-subsidize universal service in the United States. A secondary factor is the nature of price regulation in place. This is another key institutional feature in a telecommunications environment, which also needs to be simultaneously taken into account. These institutional features have a major impact in inducing firms to invest in new technology. However, there is at present little evidence which examines how these institutional features, either by themselves or each controlling for the effect of the other, influence firm-level investment patterns in new technology.

Taking advantage of data on state-level separations and variations in regulatory regimes, this study assesses how the separations and price regulation processes influence technology investments by telecommunications firms. Evidence is generated for the years 1991 to 1993, and the results obtained are expected to be of material consequence. Local exchange companies provide the primary infrastructural backbone for land-based telecommunications, and the analysis reveals how far institutional factors impact on the behavior of firms making-up that backbone.

The paper unfolds as follows: in the next section institutional issues relating to separation and regulation concerns in the telecommunications environment are discussed. Thereafter, the following section contains details of the empirical analysis carried out. The next section contains a discussion of the results obtained, while the final section concludes the paper.

INSTITUTIONAL ISSUES

NATURE AND EFFECTS OF SEPARATION

Basic Issue: The way local operating company investments and costs are allocated between state and federal regulatory jurisdictions is expected to influence the pattern of investments in new technology. A key characteristic of a telephone network is the diversity of calls that are made within the network. The three categories are: local calls, intra-state toll calls and inter-state toll calls. Inter-state toll calls are subject to federal jurisdiction, while intra-state toll calls and local calls are subject to state-level regulatory jurisdiction. In fact, the Federal Communications Commission (FCC) is expressly denied jurisdiction over intra-state services (Kellogg, Thorne and Huber, 1992). Local telephone companies' networks are used to provide all of these services. The production of these services use plant facilities which are common. This implies that after installation these facilities could be used to produce any or all of the types of calls. But the costs of intra-state and inter-state services somehow have to be separated and allocated so that each type of regulator may then determine the appropriate rate of return that may be allowed in each jurisdiction (Temin, 1987).

A principal idea driving the separations process is the notion that each local operating company is part of an end-to-end system which connects one telephone with another. It is not a discrete collection of local and toll-producing entities. Let us suppose that a toll call is made between New York and Washington; then, there are three components to the call: the connection from the New York local phone to the long-distance line, the New York-Washington long-distance connection, and the connection from the long-distance line to the Washington local phone. Yet, the call is treated as one call and not three calls. The local company infrastructure can, thus, be used to make purely local calls as well as the local component of the composite long-distance call. This principle has been well-established in the regulatory domain ever since the 1930 Supreme Court decision in *Smith vs. Illinois Bell Telephone Company* (Bolter, 1984).

As part of an end-to-end system common costs are incurred. These are the expenditure on inputs that are used in variable proportions to produce two or more services. In fact, much of telephone company investments, say, in switching, transmission and other equipment, can be classified as leading to common costs (Fenton and Stone, 1980). Kahn (1988) argues that common costs are inevitable whenever the unit of production, such as the operation and maintenance of switching and transmission capacity between two points which forms the basis of cost incurrence, is larger than the unit of sale. One such unit of sale can be a single threeminute telephone call between those two points. In other words, there are significant economies of scale which exist in the industry.

Joint costs also exist. These are the cost of inputs used in the production of two or more inputs produced in fixed proportions. For example, in the telephone industry there are peak and off-peak calling costs. Capacity installed to meet peak demand can also meet off-peak demand. A distinguishing feature between common and joint costs is that the former is space-dependent, since the use of transmission facility to transport voice uses up capacity that could be used to transport data, while the latter is time-dependent since costs of peak and off-peak capacity are related to time (Bolter, 1984). In other words, there are economies of scope which exist.

Accounting difficulties, however, exist in finding true joint and common costs. For example, an increase in the number of circuits does increase capacity which can be allocated between day and night calls in fixed proportions. Yet, these circuits can also be used to provide a varying proportion of residential and business calls or local and long-distance calls (Fuss and Waverman, 1981). Therefore, joint and common costs are treated as a single aggregate of shared costs arising from the total local operating company network investment, to be allocated between state and federal regulatory jurisdictions which have individual responsibilities for regulating the local and long-distance segments of the industry (Brauetigam, 1980).

The allocation is carried out via a separations process, according to the modalities of which shared investments and costs are subject to apportionment on the basis of relative use of the telephone infrastructure. This is undertaken by a Federal-State Joint Board, which from 1947 undertook cost allocations based on a manual developed jointly by the FCC and the National Association of Regulatory Utility Commissioners (NARUC). In spite of the existence of the detailed *Separations Manual*, the actual allocations between local and long-distance jurisdictions are often economically arbitrary. Such arbitrariness arises because it is difficult to define where the boundaries of local services end long-distance services start. How much of the local loop consists purely of the local segment, and how much is the long-distance segment is quite difficult to define precisely (Bolter, 1984).

Historical Issues and Theoretical Implications: Even if the economic arbitrariness highlighted above were avoidable, regulators have historically attempted to cross-subsidize local exchange rates by allocating a greater proportion of the shared costs to the inter-state long-distance jurisdiction, so that a large element of local exchange costs are recovered in long-distance rates. In the absence of detailed econometric studies, the allocation of costs between local and long-distance segments, or between state and federal regulatory domains, is carried out via a politically-negotiated process. For example, Gabel (1967: 16) writes that: "Separation of telephone plant is a political process. As a political process, separations has been one of accommodation and adjustment. In its formal context separations appears to be a cost accounting technique........The formal complexity of separations methods is awesome..........Such complexity often conceals the character and significance of the methods which are merely devices to reach a pre-determined financial result." The political attractiveness of local service cross-subsidization, and low rates, has been of obvious benefit to local regulators. The FCC, too, has gained political credit by emphasizing one of the most populist item of its statutory mandate, the provision of universal service (Kellogg, Thorne and Huber, 1992).

Theoretically, there are two organizational consequences arising from cross-subsidization. First, it permits firms to acquire slack resources within the organization. Such organizational slack enables firms to undertake risky or expensive investments in new technology which otherwise would not have been possible (Bromiley, 1991; Cyert and March, 1963; Singh, 1986; Thompson, 1967). This is an impact with a positive outcome. Conversely, there might be a negative outcome because cross-subsidization generates x-inefficiency (Frantz, 1988; Leibenstein, 1976; Shepherd, 1983). Where firms are almost guaranteed a resource stream, then incentives to search for ways to be efficient via investments in new technology vanish.

In developing the slack resources argument, Cyert and March (1963) and Thompson (1967) have asserted that the possession of a level of slack resources is useful for firms, since it provides an essential buffer around their core activities. Without some level of slack, any reduction in cash flows results in an immediate funds shortage which then leads to consequences which may turn out to be dysfunctional. A lack of resources necessitates staff-cuts and reductions in capital expenditures, which may have negative consequences. Thus, slack helps in smoothing the implementation of operational and strategic programs. Firms use slack to buffer their technological core from the forces of environmental turbulence, and can avail of the strategic opportunities that arise. While a very low level of slack also has a positive impact on firms, forcing them to be operationally efficient, a low level of slack does not permit high-value long-term investment projects to be undertaken.

In developing the x-inefficiency argument, Leibenstein (1976) argues that the degree of environmental pressure influences the efficiency-orientation within firms. Where the economic environment is munificent, there is little adversity and firms do not perceive any pressures for change. Adequate resources are easily available and firms are not motivated to change the status-quo. Since an efficiency-orientation does not carry a high premium in a low adversity environment, firms have little incentive to seek ways of minimizing costs. When economic adversity rises limiting the availability of resources, or resource acquisition becomes difficult, then incentives to be efficient also rise. One of the consequences of such changed incentives is to make investments in cost-reducing new technologies.

The precise organizational impact of cross-subsidy has to be evaluated based on the historical and institutional context within which firms operate. The cross-subsidization phenomenon in the U.S. has been driven by the fact that identifiable long-distance costs have consistently declined over the years. Conversely, identifiable local exchange infrastructure costs have not declined, but in fact have increased over the years (Flamm, 1989). Commentators note that long-distance customers paying high rates have subsidized local customers (Kellogg, Thorne and Huber, 1992). Yet, given network effects the value of long-distance services rise only when there is a large local infrastructure in place. The result of the transfer of long-distance earnings to keep down local rates has led to the almost complete diffusion of universal telephone service in the United States. For example, between 1940 and 1980 not only did the real price of local telephone service decline 55 percent, but subscribership increased from 37 percent to over 97 percent today. Thus, the benefits for the purposes of both local and long-distance calling are obvious. This infrastructure-building outcome has not been achieved in any country of equal size.

Given the ethos of universal service, and the circumstances surrounding costs separation, local operating companies are likely to have an incentive to ensure that their investments and associated costs are allocated to the federal jurisdiction. Thus, a greater proportion of their total operating costs can be borne by inter-state long-distance carriers and recovered via long-distance rates from long-distance customers. If a higher proportion of costs are passed on to other carriers, then local companies have available to them a larger pool of financial resources with which to make investments in expanding and upgrading their networks. Conversely, since a large fraction of these costs cannot be recovered by way of prices charged to customers because local rates are stringently regulated, if local operating companies were to be made to bear a higher proportion of costs they could find their capabilities to sustain investment in modernizing the core telecommunications infrastructure being eroded.

Between 1947 and 1987, nevertheless, there was little inter-company variation in the proportion of the total local operating company plant that was allocated to the inter-state jurisdiction which could have had discernible differential impact on firm-level investment behavior. The *Separations Manual* laid down the allocation proportion. This was revised on a number of occasions. The last formal occasion was in 1970. At this time almost 3.3 percent of total network investments and costs were assigned to the inter-state jurisdiction for every 1 percent of inter-state calling. Kellogg, Thorne and Huber (1992) note that in 1984, at divestiture, over a quarter of all investments and costs were allocated to the inter-state jurisdiction though inter-state toll calls were about a tenth of all calls made. The annual subsidy from the inter-state to the intra-state sector was around $11 billion.

After the 1984 divestiture, the direct cross-subsidization of local services has been considerably reduced, though costs are still allocated between intra-state and inter-state jurisdictions. Also, all local exchange customers now pay a monthly access charge which yields at least $4 billion a year in access revenues for local companies. A more critical institutional change has been the 1987 promulgation of the Joint Cost Order by FCC. According to this order, operating companies have to file individual cost allocation manuals setting out the processes by which joint and common costs are to be allocated between intra-state and inter-state jurisdictions. The cost allocation takes place based on procedures which are self-designed by the local operating companies, and are no longer based on mandatory principles (Kellogg, Thorne and Huber, 1992). In this self-design, there are good reasons to assume that each operating company would attempt to design its cost allocation manual to favor itself. The number of local operating companies involved also means that now there is high inter-company variation in the proportion of investments and costs that are allocated between intra-state and inter-state jurisdictions.

THE PRICE REGULATION PROCESS

Basic Issue: The motivation of local exchange companies to undertake investments is also influenced by another industry-related institutional factor: the nature of price regulation in place (Bolter, 1984). This can be either rate-of-return based or based on a price-cap. The misgivings with rate-of-return regulation arise for several reasons. First, x-inefficiencies are perpetrated. Where rate-base (cost-plus) regulation exists, then companies subject to such a regulatory regime will have little incentive to minimize the size of the capital rate base, but instead make unnecessary investments in capital resulting in quite an inappropriate capital-labor ratio, since the regulators will allow a favorable return on those additional investments that go into the rate base (Averch and Johnson, 1962). Since the regulated firm is allowed to charge a price that will cover all costs, it has little incentive to reduce costs and look for ways of either searching for appropriate technology or an efficient capital-labor mix that helps reduce such costs (Noll and Rivlin, 1973; Sappington and Shepherd, 1982).

The assumptions of the Averch-Johnson model have been shown to be factually incorrect, because in practice no rate-of-return regulated firms has been allowed to change its prices to meet the rate-of-return constraint as shown in the model (Joskow, 1973). A number of empirical studies (Courville, 1974; Hayashi and Trapani, 1976; Peterson, 1975; Spann, 1974), set primarily in the context of the electric utility industry, have broadly established the behavioral impact of the regulatory scheme captured in the A-J model to hold in practice, but no evidence exists for the telecommunications industry. Whether rate-base regulation has historically retarded investments in cost-saving new technology by U.S. telecommunications firms is unknown.

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

Rate-of-return based regulation still continues to be the common practice in many state-level regulatory jurisdictions within the U.S. In many other state-level regulatory jurisdictions, however, a major policy change that has taken place is the introduction of incentive regulation. For many local exchange companies in the U.S. telecommunications industry, the regulatory regime now facing them is one where there is a cap on prices. An explicit policy objective behind the introduction of incentive regulation has been to bring about investments in new technology and improvements in productive efficiency (Braeutigam and Panzar, 1993; Federal Communications Commission, 1992).

The Nature of Incentive Regulation: Price-cap (incentive regulation) schemes are innovations which attempt to resolve problems associated with rate-of-return regulation schemes. Price-caps represent a contract between a firm and the regulator in which a price ceiling is set for a definite period of time, and subject to that ceiling firms are able to price at whatever levels are feasible. Under rate-of-return regulation, the regulator attempts to police costs but has no control over price. Under price-cap regulation, the regulator sets the price but makes no attempts to control costs, hoping that they will come down naturally. Given set price ceilings, firms are free to retain the surpluses that they earn as a results of attaining cost efficiencies, and are induced to make the necessary investments that may permit such efficiencies to be gained. Analytical results proving that price-cap regimes do induce firms to make investments in cost-reducing technologies have been provided (Cabral and Riordan, 1989).

There are three sources of differences between the two schemes which lead price-cap schemes to be superior in inducing efficiencies. First, there is an externally-determined period, set by the regulatory authority, between price reviews. Thus, there is a fixed period for firms during which to make changes to operating strategies and enjoy the benefits of reduced costs. Second, price-cap regulation schemes do not use ex-post cost data in setting prices; rather, ex-ante productivity and demand forecasts are used in price setting. Taken together, these two aspects ensure that firms are not deterred from making efficiency improvements either by fear of confiscation within the defined period that the scheme is in operation, or that future prices are an extrapolation of past costs. Third, price-cap regulation does not require a large administrative apparatus to help determine firms' costs structures (Beesley and Littlechild, 1989). Price caps are also strictly enforced in the U.S., and companies have not been allowed to make mid-course price adjustments if they have found that their costs have risen for various reasons (Kellogg, Thorne and Huber, 1995).

Apart from the key characteristic, that regulators fix a price ceiling for a period of time during which rates are not adjusted downwards by the regulatory authorities, there are three additional properties of contemporary price-cap schemes (Acton and Vogelsang, 1989). Price ceilings are generally set for clearly identified baskets of services so that cross-subsidization between the services in different baskets are sought to be avoided (Vogelsang and Finsinger, 1979). Price ceilings are also to be adjusted periodically based on a pre-announced adjustment factor, so that firms are certain as to how long a time period they have to internalize productive efficiency gains (Sudit, 1979). In longer intervals of several years, adjustment factors, baskets and weighting schemes are all reviewed and changed if necessary (Baumol, 1968).

Only two studies have empirically examined the impact of incentive regulation. Using 1983 and 1987 data, Mathios and Rogers (1989) examine cross-sectional variation in the way that different states regulate AT&T's long-distance rates. They find that federal level incentive regulation leads to lower long-distance prices. Greenstein, McMaster and Spiller (1994) use data for 1986 to 1991 to examine the effect of price-caps on local exchange telecommunications firms' investment decisions, finding that such schemes do influence deployment of cost-reducing technologies. Some evidence exists as to the impact of incentive regulation, showing that the resulting behavior of firms is consistent with theory. However, what impact the separations process has had on firms' investment behavior is an issue that remains empirically unexplored, in spite of the crucial economic and political importance of the role that cross-subsidization has played in the U.S. telecommunications industry.

EMPIRICAL ANALYSIS

To evaluate the impact of the separation and incentive regulation processes on the investment behavior of firms, the study uses firm-level data for a balanced panel of 45 local operating companies obtained from the *Statistics of Communications Common Carriers* for the years 1991 to 1993. Data are collated by the FCC, based on periodic reports that are submitted by the companies and published annually. The companies account for 99 percent of installed telephone lines in the United States, and the data for these companies are contemporary; hence, the results have immediate policy implications. The nature of the data also enable control of other factors that can influence investments in new technology. The period is one during which a number of states have moved from rate-of-return to some form of incentive regulation. There is cross-sectional as well as time-wise variation in respect of the regulatory regimes that local operating companies face, providing ideal natural experiment conditions.

Dependent Variables: Detailed descriptions of the independent and dependent variables are given in Table 1.

[INSERT TABLE 1 HERE]

Investment in new technology is measured by two continuous variables. The first is *FIBER*, which is the fiber optic intensity in each local operating company's network. The second is *DIGITAL*, measuring the proportion of a local operating company's lines that are digitized, in each of the years studied. Both of these technologies have cost-reduction benefits for the deploying firms (Egan, 1991). In evaluating impact new technology investment patterns, comparable digitization data are not available for earlier years. The standard reporting format in respect of accounting data and operational plant statistics that the local operating companies have had to submit to the FCC, then in existence for over thirty years, was radically changed after 1987. A new Uniform System of Accounts was introduced so that the FCC could monitor the implementation of its Joint Cost Order (Kellogg, Thorne and Huber, 1992).

The data reported by FCC are for absolute values of fiber miles for both fiber-to-the-curb and fiber-to-the-home deployed in the system and a figure for each type of deployment is not separately available. For the analysis, *FIBER* is scaled by a measure of size and calculated as miles of fiber relative to the total lines in the network. This gives an indication of the relative intensity of fiber optic usage for each firm. Until 1987 firms reported the composition of their installed base of switches as to whether they were electronic or electro-mechanical, and the impact of several firm and industry-related factors influencing new technology adoption were studied using these data (Majumdar, 1995). From 1988 data are reported in a new format. In 1991 the format for reporting plant statistics was, however, again changed. Now different aspects of firm-level plant and technology composition details are now being reported. The specific changes in format relate to the reporting of digitization data; this was again re-classified from 1991 onwards. Therefore, digitization data for the years 1988 to 1990 are not comparable with data for the years 1991 onwards.

Institutional Variables: To evaluate the impact of the separations process on new technology investments, a variable - *SEPARATION* - is constructed using data that are obtained from the FCC Monitoring Report (1993). The report is prepared by the Federal-State Joint Board. It identifies for each local operating company their total plant investment and the amounts of these allocated specifically to state as well as federal jurisdictions. 1993 is the first year during which investment data allocated among federal and state jurisdictions for separations purposes were released. The Monitoring Report is periodically issued, starting with the first report published in 1988, to help policy-makers and other interested parties monitor the impact of FCC decisions. Since 1992 the mandate of the monitoring program has been extended for five years, till 1997. Annual reports are to be provided every May from 1993 onwards. At that time, starting with the May 1993 report, the FCC decided to add a new section to the Monitoring Report which would consist of investment and other data subject to separations allocation between intra-state and inter-state jurisdictions based on FCC rules. Using data from the May 1993 Monitoring Report, *SEPARATION* is measured as the relative proportion of total investments allocated to the inter-state jurisdiction. The larger this proportion for local operating companies, the larger is the pool of resources available for aggressive investing and the stronger are the possibilities for investing in new technologies. Thus, given the conceptual arguments underlying the separations process issue, the coefficient of *SEPARATION* is expected to be positive.

Given the existence of two-tiered price regulation, state and federal, a principal difference between federal and local level price regulation is that at the local level rate-of-return constraints continue to operate in conjunction with price-cap schemes (Braeutigam and Panzar, 1993). In such circumstances a price-cap plan is coupled with an earnings sharing scheme, with provisions for adjusting prices if the firm's earnings fall outside a certain range. Price-cap schemes can also have a price-freeze component, as a result of which the abilities of companies to price flexibly reduce (Greenstein, McMaster and Spiller, 1994). Under a price-freeze companies cannot necessarily reduce prices, but they do face a price-ceiling as they would anyway when faced with a flexible pricing regime. Since a price-cap regime induces behavioral changes in firms as a result of the price-ceiling enforced, it is a price-minus regime in practical terms. Therefore, the behavioral consequences of frozen versus flexible prices in a price-cap regime are likely to be similar with respect to inducing behavioral effects.

A common form of earnings sharing is one where the telephone company is allowed to retain all earnings allowing a specified level of return, then retain half of all subsequent additional earnings permitting the company to earn, say, an additional percentage point rate-of-return, and thereafter it has to refund earnings above that level (Braeutigam and Panzar, 1993). In addition, a number of states have implemented schemes where there is only an earnings sharing scheme but no price-cap plan in effect. This regulatory regime is similar to a rate-of-return regime in impact.

A number of state-level classifications of regulatory regimes in the U.S. exist, and the Greenstein, McMaster and Spiller (1994) documentation of the regulatory conditions faced by each individual firm is used for the analysis. *PRICE CAP* is a variable taking on the value of 1 if the state in which a firm operates has implemented pure price-cap regulation in the various years that are studied, and 0 otherwise. The base-case is a rate-of-return regulatory regime. Between 1987 and 1993, many states, for example: Kansas, Maine, Nebraska and Wisconsin, have implemented such a regulatory scheme. Also, within a state two operating companies need not face the same set of institutional rules; for example, in Michigan different regulatory schemes may exist for GTE Midwest and Michigan Bell. Hence, information on firm-specific regulatory regimes is useful isolating the specific effects of incentive regulation regimes faced by firms.

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

A number of states operate an earnings sharing system in conjunction with a price-cap regime. For example, to regulate Chesapeake and Potomac Telephone Company - C&P - (renamed Bell Atlantic: D. C. and the monopoly service provider in the District of Columbia) a price-cap scheme has been adopted in consonance with an earnings sharing scheme from January 1993. Under the scheme C&P retains all earnings between 11.5 and 13.5 percent, but splits half of all excess earnings yielding a return greater than 13.5 percent with rate-payers (Greenstein, McMaster and Spiller, 1994). Some other states where similar combined schemes are in operation are: California, Florida, New York and Texas. For single-state operating companies a variable, coded 1, is used to denote the existence of a price-cap scheme which is coupled with an earnings sharing component for the years studied and 0 a rate-of-return based regime.

For multi-state operating companies the *CAP & SHARING* index is constructed in a manner similar to the procedures used for constructing the *PRICE CAP* index. Whether a pure price-cap scheme is better than one which combines an earnings sharing component has to be empirically determined, but theory suggests that a pure price-cap scheme will have superior properties, and *CAP & SHARING* is likely to have a weaker effect on the dependent variables as compared with *PRICE CAP*. While a pure earnings sharing scheme is conceptually similar to rate-of-return based regulation in its behavioral impact, a number of states have implemented such schemes as an alternative to either rate-of-return or any other form of incentive regulation. Where this is the case in any state, the coding pattern and index-creation procedures followed for creating the variable *SHARING* are the same that have been followed for creating *PRICE CAP* and *CAP & SHARING*.

Control Variables: A number of control variables are included, since new technology investment decisions can be affected by factors other than those which are institutional. The business environment of local operating companies has changed in the 1990s, but particularly with the passage of the 1996 Telecommunications Bill. Competitive pressures exist in both toll and local call markets, though in varying degrees. In inter-LATA toll markets competition is intense; local operating companies have demanded the right of entry, and are soon to be permitted entry into the inter-LATA market. In intra-LATA markets, where local companies have had a service monopoly, competition has been less intense, though a number of major states permit competition. The number of states opening up this market to other entrants has increased every year. Intra-LATA toll calls account for almost a third of all calls accounted for by a local company. The variable *TOLL REVENUE*, which is the percent of toll revenues to total revenues, helps capture the exposure of companies in toll markets. The greater such pressures are, the higher is the inducement to make new technology investments.

In the local segment the threat of bypass, a direct connection between a customer's premises and another carrier or a self-contained system avoiding the operating company's system fully (Weisman, 1988), is significant. Such threats may induce a search for efficiencies, since revenues are lost through bypass but all costs still have to be incurred to maintain the network in its present existing size and condition. Business customers are fewer in number, but their average spending is much greater than residential customers. They are important for revenue-raising purposes since their consumption economies are high. They are also the customers most likely to bypass the local network (Bolter, McConnaughey and Kelsey, 1990). *BUSINESS LINES*, which is the percentage of a firms's lines that are business lines, measures the susceptibility of bypass. It also captures the consumption characteristics of a firm's markets, which Kamien and Schwartz (1982) argue are important in inducing new technology investments. Both these factors are expected to positively induce new technology investments.

SWITCH SHARE, measured as the percentage of switches a company possesses in its given operating area relative to the total number of switches all firms possess in that operating area, captures relative share of installed base. Though the proportion is mandated, the measure controls for an element of relative territorial power possessed by each local operating company. The issue of relative market power is conceptually important. Schumpeter (1975) recognized that firms required some sort of a monopoly position so as to reap the benefits from the expensive investments that they undertook. Also, a market consisting of only a few players made the environment more stable, thereby reducing uncertainty and increasing the inducements to undertake investment activities. While these views are supported by some (Demsetz, 1969), others (Arrow, 1962; Fellner, 1951) have shown that firms stand to gain more from their investment activities in competitive rather than in high-concentration situations. Conversely, there is the issue that insulation from competitive pressure discourages innovative activity (Leibenstein, 1976).

The size and investment relationship has been extensively examined (Cohen and Levin, 1989; Davies, 1979), and *SIZE* is introduced as a control variable. Larger firms have a greater amount of capital to experiment with. If experiment are successful a large firm can become larger and more effectively control its environment (Pfeffer and Salancik, 1978). Therefore, the prospect of such gains raises the odds in favor of large firms making investments in technologies which may seem risky (Nutter, 1956). Larger firms, by definition, have a greater volume of output to spread costs over and can enjoy conversion economies. If the innovative activity is successful, then there are also larger absolute gains to be made by the firm (Galbraith, 1952).

Alternatively, as firms become larger efficiency in innovative activities diminish (Williamson, 1975). With increasing size, incentives to pursue innovative activities reduce since the gains from such activities are more widely shared. Conversely, smaller firms are more flexible and can adapt where rapid decision-making with respect to innovative activities is required (Carlsson, 1989). Prior research using data for 1987 (Majumdar, 1995) has found size to be weakly but negatively related to adoption decisions. Whether transformation has taken place in the behavior of local operating companies in the intervening period of time, and how size is presently related to technology investment is an empirical issue. If size is found to be positive, then such results will also indicate that a behavioral transformation is taking place among the local operating companies in the U.S. telecommunications industry. With respect to the *SWITCH SHARE* and *SIZE* variables, the predictions from theory can go either way. In the telecommunications context, however, both these variable confer economies of conversion that are necessary in changing from one technology to another in a network industry. The conversion effect is quite crucial in a network context (Antonelli, 1991). Hence, it is expected that the impact of *SWITCH SHARE* and *SIZE* are likely to be positive given the contemporary empirical context of the present study.

Ownership is a key determinant of investment behavior (Leibensten, 1976), particularly in the telecommunications industry (Flamm, 1989). Research establishes that the erstwhile AT&T-owned operating companies, called Baby Bells after 1984, have made radical changes to outstrip the other independent companies in strategic performance in the post-divestiture period (Schlesinger, Dyer, Clough and Landau, 1987). *OWNERSHIP* is constructed as a dummy variable, taking on the value of 1 if the observation is a Baby Bell company, and taking the value 0 otherwise. A higher quality of human capital in firms can be positively correlated with pro-active behavior in investing in new technology. *COMPENSATION*, measured as the average dollar value of compensation paid per employee, helps capture differences in the firm-level human capital and management quality (Mefford, 1986). An assumption can be made that firms which make investments in people-embodied capabilities are also the ones likely to make investments in technological capabilities. The variable helps evaluate if a higher level of human capital quality positively explains differences in firms' propensities for proactive technology investments.

RESULTS

A pooled model, with corrections for cross-sectional heteroscedaticity and time-wise auto-regression, is used for estimating the regression model. The specific model used is one recommended by Kmenta (1986), which assumes heteroscedasticity and auto-regression but cross-sectional independence. Because the time-series is so short, the auto-correlation coefficient is constrained to be the same across all cross-sectional observations. A correlation matrix for the regressors is given in Table 2. No multi-collinearity problems seem apparent from the data.

[INSERT TABLE 2 HERE]

The estimation results are given in Tables 3 and 4. Table 3 contains regression results where the dependent variable in the various models is the logged values of *FIBER*, while Table 4 contains results where the dependent variable in the different models is the logged value of DIGITAL. For each dependent variable, 6 models are estimated. For example, equations 1 and 2 include *SEPARATION* without and with control variables respectively for the dependent variable *FIBER*. Equation 3 leaves out *SEPARATION* but includes the three regulatory regime variables: *PRICE CAP*, *CAP & SHARING* and *SHARING*; equation 4 includes these three variables as well as the control variables. Equation 5 includes *SEPARATION* and the three regulatory variables: *PRICE CAP*, *CAP & SHARING* and *SHARING*. Hence, the nature of price regulation is introduced as a control when the impact of cross-subsidization is evaluated, and vice-versa. Equation 6 includes all the variables. Results in Table 3 are discussed first.

[INSERT TABLE 3 HERE]

Deployment of Fiber Optics Technology: The results in Table 3 show that *SEPARATION*, which captures the effect of the cost allocations process on firms' investment behavior, is positive and significant when regressed alone or in conjunction with the control variables, as equations 1 and 2 show. In equations 5 and 6 *SEPARATION* is also positive and significant, when the nature of regulation in place is also introduced as a control factor. Thus, whether or not control variables are included in the various models, *SEPARATION* is positive in the various equations. The results suggest that firms are induced by the modalities of the separation process, which captures the relative size of cost allocation to the inter-state regulatory jurisdiction, in making investments in new technology. Theoretically, the organizational slack resources hypothesis (Cyert and March, 1963; Thompson, 1967) is supported by the data.

The regulatory regime variables enter in equations 3 to 6. In equation 3 they enter the model alone, while in equation 4 they enter the model along with the other control variables. In both these equations *PRICE CAP* is positive and significant, denoting that a shift from a rate-of-return regime to incentive regulation does induce firms to make investments in cost-saving technologies. In equations 5 and 6 *SEPARATION* is also introduced as a regressor. Controlling for the impact of the separations process, the *PRICE CAP* variable stays positive and significant.

In these four equations (equations 3 to 6) *CAP & SHARING* is negative and either non-significant (equations 3 and 5) or significant (equations 4 and 6) while *SHARING* is positive and significant in equations 4 and 6, but positive in equations 3 and 5. These results imply that a partial shift away from rate-of-return regulation has relatively limited impact in inducing new technology investment, as captured by *FIBER*. A shift to an earnings-sharing regime retains some similarity with a rate-of-return regime, and its impact can be readily gauged by firms. Thus, the effect of *SHARING* is positive. The shift to a price-cap-cum-earnings-sharing regime mixes two regulatory schemes. Its impact may not be easily discerned by firms and sends mixed signals. Such signals may quite easily confuse the firms affected, hence leading to the negative coefficient for *CAP & SHARING*.

The results for the control variables are commented on next. *TOLL REVENUE* is found to positively and significantly impact the deployment of fiber optics technology in all of the equations it enters. *BUSINESS LINES* is positive and significant in equation 2 as expected, but surprisingly negative and significant in equations 4 and 6. The regulatory regime variables enter in equations 4 and 6. It is possible that the threat of local exchange bypass is over-shadowed by the potential efficiency gains that incentive regulation engenders.

SWITCH SHARE is positively and significantly related to fiber optics deployment. *SIZE* is also positive and significant in inducing investments in digital technology. Since, past research using older data (Majumdar, 1995) had found size to be negative and significant, the results of contemporary data analysis suggest that transformation is taking place among the larger firms in the sector, which can leverage a greater variety of internal resources for attaining strategic performance goals, and for these firms it makes sense to be proactive in new technology deployment. Also, the potential to enjoy network conversion economies is a possible factor that firms seem to consider in making technology investments in the new technology.

OWNERSHIP is positive and significant with respect to fiber deployment. The Baby Bells are, thus, more aggressive in the contemporary period in undertaking technology upgradation of their infrastructure. Finally, *COMPENSATION* is positive and significant with respect to fiber optic deployment. The variable is expected to pick up differences in human capital quality between firms. The expectation is that firms with relatively superior human capital are also likely to be strategically pro-active. Assuming that such pro-activeness can be captured as new technology deployment, the results indicate that higher quality human capital does lead to strategic pro-activeness. Table 4 contains results where the dependent variable is *DIGITAL*.

[INSERT TABLE 4 HERE]

Deployment of Digital Technology: The results in Table 4 broadly mirror the results shown in Table 3. *SEPARATION* is significant across equations 7, 8, 11 and 12. *PRICE CAP* is significant in all relevant equations but not positive. Conversely, *SHARING & CAP* turns out to be significant in two of the equations: 9 and 11, while *SHARING* is significant in equations 10 and 12. The results show that the separations process retains its ability to spur technology deployment, where the technology in question is now digital lines. The introduction of incentive regulation does not have quite the same impact on digital electronics deployment. On the other hand, the deployment of digital electronics technology in the United States is actually quite low because of the existence of a very large installed-base of analog electronic technology (Antonelli, 1991). Therefore, a strong positive relationship between incentive regulation schemes and digital technology deployment is likely to be noticed in the years ahead as further states shift to incentive regulation and digital technology diffuses further. The results with respect to how the control variables impact on *DIGITAL* are broadly similar to those reported in Table 3.

Assessment of the Relative Impact of Separation versus Regulation:

Also of interest is evidence with respect to the relative impact that the separations process has vis-a-vis the regulatory regime shifts. The standardized values of the coefficient estimates for equations 5 and 6 (from Table 3) and equations 11 and 12 (from Table 4) are given in Table 5.

[INSERT TABLE 5 HERE]

The data in Table 5 indicate that *SEPARATION* has had a considerably stronger impact than the regulatory regimes in influencing the deployment of both fiber optics and digital technology. Among the regulatory regime variables *PRICE CAP* has the strongest impact in influencing new technology deployment. The impact between the two types of technologies also differ. There is a stronger impact of both the *SEPARATION* and *PRICE CAP* variables in influencing the deployment of fiber optics relative to their influence on the deployment of digital technology. Again, the very large installed base of analog electronic technology, which was put into place not that long ago, may be slowing the progress of network digitization and institutional incentives may not yet have a significant role to play in influencing digitization.

Relative to the introduction of incentive regulation, the availability of cross-subsidy does have a considerably stronger impact in influencing new technology deployment in the U.S. telecommunications industry. The introduction of incentive regulation, when not compromised by introducing a mixed scheme, also has a strong impact relative to the situations where either a mixed scheme is introduced, or where the scheme introduced is broadly similar to the erstwhile rate-of-return based scheme. This evidence is consistent with the data generated by Greenstein, McMaster and Spiller (1994) for an earlier time-period. Thus, changes in institutional incentives do have an impact in influencing technology deployment decisions.

DISCUSSION AND IMPLICATIONS

Implications for the Literature: While a number of studies of how a variety of exogenous and endogenous variables impact investments in new technology exist in the literature, there is a surprising absence of studies assessing the impact of institutional factors. From both theoretical and empirical perspectives, this study sheds light on how institutional factors influence investments in new technology, while controlling for a host of factors which have been recognized in the literature as also likely to have an impact. It thus represents a contribution to the literature on technical change, and at the same time is based on contemporary data for an industry which is one of the most crucial in the contemporary economic environment.

Cross-Subsidization - Policy Implications: The implications of the findings are of considerable consequence. Though, as earlier noted, cross-subsidization has indeed played a fundamental historical role in helping create the present land-based U.S. telecommunications infrastructure, it has come in for wide-spread criticism (Baumol and Sidak, 1993; Bolter, 1984; Kahn, 1988; Kellogg, Thorne and Huber, 1992; Mitchell and Vogelsang, 1991; Zajac, 1978). This is because it violates a major principle in pricing articulated by Ramsey (1927). The Ramsey rule articulates the idea that the largest share of sunk costs should be allocated to users who most need the service, in other words to those individuals whose demand elasticity is the lowest, and who do not have any other alternatives to change to. While perhaps fair in a narrow technical sense, the application of the principle implies that the real price of local telephone services would have been considerably greater. Also, the national telecommunications infrastructure would not have been created, because the consumers could not pay for the services offered.

The results reported in this paper shows that in the contemporary telecommunications industry context, where diffusion of universal service is no longer an issue, cross-subsidization provides firms the ability to make investments in new technology, rather than being the cause of x-inefficiencies. Thereby, the quality of the national telecommunications infrastructure is considerably enhanced. Whether local services are provided, or whether long-distance services are to be consumed, the local operating company infrastructure backbone will always be necessary for the final connection. If diffusion of fiber optics and digital technology takes place within this infrastructure, the benefits have extremely wide impact on firms within a network industry and on consumers. Therefore, cross-subsidization can create the high-quality core telecommunications infrastructure of tomorrow, just as it created the infrastructure of yesterday.

Incentive Regulation - Policy Implications: The data imply that the introduction of incentive regulation in the various states also positively induces investment in the new fiber and digital technology, as firms seek means to enhance their efficiencies. While the introduction of incentive regulation has been welcomed, it does represent an institutional policy change as a result of which the behavior of firms change. Nevertheless, it is to be stressed that a complete change from rate-of-return based regulation to incentive regulation has the most impact. This is the recommendation for regulatory regimes contemplating a change. Any other policy change, either involving a mixed price-cap-cum earning-sharing scheme or an earnings-sharing scheme has considerably lesser impact. In fact, the introduction of mixed schemes is likely to send mixed signals to firms, resulting in considerable confusion and sub-optimal behavior.

Technology Diffusion - The Operational Implications: The above comments do not have value if investing in new technology does not have positive operational pay-offs. Therefore, the consequences of new technology investment need to be described. An advantage fiber optic cable has over copper cable is the amount of bandwidth capacity. A fiber optic cable can conservatively carry 16,000 phone calls at once compared to the 24 calls that copper wire can handle, a 667-fold increase in capacity (Therrien, 1989). Apart from voice and data handling advantages, other benefits are associated with fiber optics. First, longer transmission distances are possible. Second, installation is considerably easier as the weight differential is significant. Third, with high humidity copper corrodes and replacement of wire is necessary so as to stop signal degradation. Fiber optic cables last longer, and also enhance transmission quality by suppressing electrical noise since glass cannot conduct electricity (West, 1986).

Fiber systems also yield efficiencies in deployment, since electronic components can be utilized among a greater installed-base of customers (Selander, 1990). The arrangement involves deploying fiber to an interface point near the customers, which in newer construction sites are referred to as pedestals. Sharing of expensive opto-electronic equipment is then possible, and coaxial or other copper wire is used for the short link to the subscriber. Additionally, such increases in components usage increases channel capacity and reduces maintenance down-time, thus yielding local exchange operating efficiencies (Egan, 1991).

The experiences of Pacific Bell also reveal how the deployment of fiber optics permits efficiencies to be gained. Two main operations support activities are benefitted because fiber optics helps create an intelligent network. First, co-axial voice and data paths and a fiber optic based intelligent network interface unit, in conjunction with digital technology, eliminates main distribution frames and replaces wire-junctions with a computer keyboard for connecting circuits. Second, fiber optics simplifies network topology. Multiple points of interconnection between the main distribution frame to customers premises are replaced with a frequency-agile system, which permits bandwidth to be allocated at will, rather than be dedicated to individual customers. This helps in centralizing network management (Swenson, 1994). It is estimated that annual costs savings per access line are $50. The annual savings for the industry as a whole are, therefore, substantial, given that there are over one hundred million residential access lines in the U.S.

Digital systems can directly connect-up with various modes of switching systems and data circuits, enhancing the utilization of assets already in the system. In addition, digital transmission units are more compact and suitable for short and medium-haul transmissions of voice and data which fall under the purview of local operating companies (Flamm, 1989). Other than the dramatic improvement in transmission quality arising from a different methodology of transmission, the major operational advantage of digital over analog channel banks is the possibility to plug-in modular units, thus enabling a system to be expanded or contracted easily.

In a technical sense, the availability of modular plug-in units enhance system flexibility and usage greatly, because contained within these plug-in units are electrical functions, such as integrated signaling, wide-band transmission and data transmission, to provide which would require the use of additional externally-placed capital equipment in analog systems. Contemporary channel banks can be remotely accessed, and units can be remotely adjusted. Through the remote access facility, transmission levels setting and maintenance testing can be carried out, enhancing considerably the operating efficiency of the transmission and the overall telephone system (Green, 1992). Additionally, maintenance costs are dramatically reduced because automatic error correction and detection reduce manpower requirements (Antonelli, 1991).

Other than technical consequences, there are managerial implications arising from the deployment of modular digital equipment. First, since a telephone or a telecommunications networks consists of a number of inter-related components, there are systems-scale economies arising as new efficiency-enhancing technology are deployed within the system (David and Bunn, 1988). As a greater proportion of digital technology is used within a given telephone company's network, the benefits of these economies accelerate because of a process of increasing returns.

Digital technology does not involve radical technical change, which can fully destroy firms' competencies. Rather, it involves modular technical change which makes its impact on firms less dramatically (Henderson and Clark, 1990). Because modular change does not render obsolete the linkages that exist between components of a system, the technology that is being adopted can be blended-in through the use of existing system-management capabilities, though the blending-in is not entirely cost-free, particularly if the transition involves a direct bypass from the electro-mechanical generation to the digital generation by skipping the entire analog electronic generation (Antonelli, 1991).

With respect to blending-in, Rosenberg (1988: 25-26) remarks that: "it makes an enormous difference whether a new technology requires the purchase and introduction of new equipment (especially when such equipment involves large fixed costs) or whether it can be added on or introduced a modification to existing equipment. The prospects for technology blending will be very much shaped by the ease with which new technology can be introduced without having to scrap the old. In the extreme case, if a new technology requires the complete scrapping of an old one in order to take advantage of it, no blending is possible." The diffusion of digital technology not only requires no system-scrapping (Green, 1992), but augments the overall systems-scale economies enjoyed in a network-based telephone system (David and Bunn, 1988).

Future Work: The present paper has looked in detail at how institutional changes do impact on technology investment decisions. In the context of the telecommunications industry, the way how fiber optics and digital technology impacts on firms operationally has also been discussed in detail in the preceding paragraphs. An important issue with managerial and policy consequences, worthy of immediate empirical exploration, is the extent to which the deployment of fiber optic and digital technologies does impact on the performance of firms.

A large literature evaluates the theme that efficiency growth is a function of the quality embodied in the capital base. In other words, an explanation for the existence of the residual in productivity growth that Solow (1957) identified lies in capital quality (Domar, 1963; Salter, 1966). Contributions to this literature have been aggregative in their approach, but several researchers (Clark, 1987; Nelson and Winter, 1982) stress the need for firm-level analysis. Yet, little firm-level evidence exists on the performance impact of the diffusion of new technology. Studies taking a micro-level approach in evaluating whether decisions taken by firms in upgrading the quality of their network infrastructure has had a measurable impact on performance are needed, given the importance of new technology investment and its diffusion within firms. Such analyses will augment in a major way the literature on firm-level behavior and performance.

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TABLE 1: DESCRIPTION OF VARIABLES

VARIABLE	DESCRIPTION
FIBER	Log of the proportion of fiber optic lines relative to the total lines that are operated by a local exchange company. (Source: FCC, Common Carrier Statistics)
DIGITAL	Log of the proportion of a company's access lines that are digitized. (Source: FCC, Common Carrier Statistics)
SEPARATION	The percentage of an operating company's total investment that is allocated to the inter-state jurisdiction via the separations process. (Source: FCC, Monitoring Report (1993))
PRICE CAP	A variable which for single-state operating companies equals 1 if pure price cap regulation exists in the state that the company operates in, and 0 otherwise; for multi-state operating companies a composite index variable is constructed, with 1 denoting the existence of pure price cap regulation, and 0 otherwise, for each of the states the company operates in, by weighting the presence of price cap regulation in each such state by the proportion of total loops contributed by that state to the total number of local loops operated by the company. (Sources: FCC, Monitoring Report (1993) and Greenstein, Mc Master and Spiller (1994))
SHARING & CAP	A variable that for single-state operating companies equals 1 if price cap regulation combined with an earnings sharing scheme exists in the state that the company operates in, and 0 otherwise; for multi-state operating companies an index variable is constructed following the approach used for the *PRICE CAP* variable. (Sources: FCC, Monitoring Report (1993) and Greenstein, Mc Master and Spiller (1994))
SHARING	A variable that for single-state operating companies equals 1 if an earnings sharing scheme exists in the state that the company operates in, and 0 otherwise; for multi-state operating companies an index variable is constructed following the approach used for the *PRICE CAP* and *SHARING & CAP* variables. (Sources: FCC, Monitoring Report (1993) and Greenstein, Mc Master and Spiller (1994))
TOLL REVENUES	The percentage of toll revenues relative to the total revenues for each operating company. (Source: FCC, Common Carrier Statistics)
BUSINESS LINES	The percentage of business lines relative to the total number of lines for each company. (Source: FCC, Common Carrier Statistics)
SWITCH SHARE	The percentage of switches operated by each company relative to the total switches that are operated in its operating territory. (Source: FCC, Common Carrier Statistics)
SIZE	The log of deflated total revenues for each company. (Source: FCC, Common Carrier Statistics)
OWNERSHIP	A dummy variable which equals 1 if the observation is one of the Baby Bell companies and 0 otherwise if an independent operating company. (Source: FCC, Common Carrier Statistics)
COMPENSATION	The average \$ value of compensation per employee. (Source: FCC, Common Carrier Statistics)

TABLE 2: CORRELATION MATRIX

Variable	1	2	3	4	5	6	7	8	9	10
1. *SEPARATION*	1.00									
2. *PRICE CAP*	-0.17	1.00								
3. *SHARING & CAP*	-0.00	0.06	1.00							
4. *SHARING*	-0.37	0.05	-0.77	1.00						
5. *TOLL REVENUE*	0.22	-0.01	0.09	-0.06	1.00					
6. *BUSINESS LINE*	-0.28	0.02	0.14	-0.02	0.07	1.00				
7. *SWITCH SHARE*	-0.26	-0.09	-0.32	0.31	-0.38	-0.35	1.00			
8. *SIZE*	0.03	0.19	0.19	-0.01	-0.04	0.15	-0.33	1.00		
9. *OWNERSHIP*	-0.02	-0.08	-0.22	0.09	0.16	0.35	0.06	-0.66	1.00	
10. *COMPENSATION*	0.08	0.14	0.14	-0.11	0.21	0.07	-0.19	0.08	-0.20	1.00

TABLE 3: REGRESSION RESULTS: THE IMPACT OF SEPARATION AND INCENTIVE REGULATION ON INVESTMENT IN FIBER OPTICS TECHNOLOGY - Dependent Variable: Log *FIBER*

Variable	Equation 1	Equation 2	Equation 3	Equation 4	Equation 5	Equation 6
Constant	0.138	-0.883	1.219	0.452	0.084	-1.394
	(0.44)	(1.30)	(32.19)	(1.09)	(0.25)	(2.18)
SEPARATION	0.055**	0.054**			0.046**	0.055**
	(4.56)	(3.27)			(3.49)	(3.60)
PRICE CAP			0.338**	0.348**	0.231**	0.336**
			(3.24)	(2.39)	(2.47)	(2.12)
CAP & SHARING			-0.038	-0.197*	-0.114	-0.266**
			(0.28)	(1.80)	(0.83)	(2.44)
SHARING			0.086	0.122*	0.066	0.199**
			(0.95)	(1.55)	(0.91)	(2.81)
TOLL REVENUE		0.007**		0.005*		0.009**
		(1.97)		(1.45)		(2.45)
BUSINESS LINE		0.030**		-0.024**		-0.027**
		(5.90)		(4.43)		(5.03)
SWITCH SHARE		0.003**		0.005**		0.003**
		(2.22)		(3.91)		(2.34)
SIZE		0.037*		0.020		0.057**
		(1.29)		(0.75)		(2.03)
OWNERSHIP		0.302**		0.293**		0.214**
		(3.04)		(3.05)		(2.17)
COMPENSATION		0.016**		0.017**		0.192**
		(3.33)		(3.71)		(4.07)

t-statistics in parentheses; ** p<.05 (one-tailed), * p<.10 (one-tailed)

TABLE 4: REGRESSION RESULTS: THE IMPACT OF SEPARATION
AND INCENTIVE REGULATION ON INVESTMENT IN DIGITAL TECHNOLOGY
Dependent Variable: Log *DIGITAL*

Variable	Equation 7	Equation 8	Equation 9	Equation 10	Equation 11	Equation 12
Constant	-4.531	-31.763	-2.479	-22.272	-5.920	32.422
	(1.11)	(6.70)	(7.57)	(7.00)	(2.79)	(6.89)
SEPARATION	0.088*	0.231**			0.139**	0.226**
	(1.64)	(2.46)			(1.71)	(2.34)
PRICE CAP			0.853	0.849	0.721	0.977
			(1.00)	(1.07)	(1.02)	(1.18)
CAP & SHARING			0.624**	-0.085	0.720*	-0.165
			(1.67)	(0.20)	(1.56)	(0.42)
SHARING			0.145	0.597*	0.066	0.568**
			(0.41)	(1.61)	(0.15)	(1.69)
TOLL REVENUE		0.032**		0.022**		0.034**
		(2.41)		(1.67)		(2.60)
BUSINESS LINE		0.038*		0.051**		0.045*
		(1.39)		(1.71)		(1.59)
SWITCH SHARE		0.012*		-0.004		-0.012*
		(1.28)		(0.43)		(1.30)
SIZE		1.080**		0.726**		1.123**
		(5.19)		(3.73)		(5.63)
OWNERSHIP		3.924**		3.627**		2.773**
		(3.68)		(4.48)		(3.50)
COMPENSATION		0.122**		0.136**		0.119**
		(3.96)		(4.20)		(3.88)

t-statistics in parentheses; ** p<.05 (one-tailed), * p<.10 (one-tailed)

TABLE 5: EXAMINING THE RELATIVE IMPACT OF SEPARATION VERSUS INCENTIVE REGULATION ON INVESTMENT IN NEW TECHNOLOGY: STANDARDIZED COEFFICIENT ESTIMATES

Variable	Log *FIBER*	Log *FIBER*	Log *DIGITAL*	Log *DIGITAL*
SEPARATION	0.204	0.248	0.080	0.129
PRICE CAP	0.097	0.141	0.039	0.052
CAP & SHARING	-0.067	-0.157	0.055	-0.012
SHARING	0.045	0.135	0.006	0.049
TOLL REVENUE		0.145		0.071
BUSINESS LINE		-0.355		0.076
SWITCH SHARE		0.157		-0.078
SIZE		0.126		0.318
OWNERSHIP		0.179		0.296
COMPENSATION		0.163		0.130