# COMPETITION'S EFFECT ON INVESTMENT IN DIGITAL INFRASTRUCTURE*

GLENN A. WOROCH
Department of Economics
University of California at Berkeley
Berkeley, CA 94720-3880
510-642-4308
glenn@econ.berkeley.edu

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## *Abstract*

Competition has become a preferred means to promote investment in digital infrastructure. The U.S. Telecom Act, the WTO Reference Paper and EC Directives each adopt policies that encourage facilities-based entry into telecommunications markets to expand service coverage and to accelerate deployment of advanced technologies. Yet despite its popularity, empirical evidence that this policy stimulates infrastructure investment–either directly through entrants' construction activity or indirectly through competitive pressures applied to incumbents–is lacking.

This paper examines the effect of facilities-based competition on one specific type of digital infrastructure investment. A panel data set was collected on the deployment of digital fiber ring networks in largest U.S. cities over the 10-year period 1983-1992 by incumbent local exchange carriers (ILECs) and competitive local exchange carriers (CLECs). These networks provide high-speed access for large business customers. Controlling for state and federal regulation of rates and investment and for local economic conditions, standard exogeneity and causality tests reveal that CLEC entry leads to subsequent ILEC investment and that, with slightly less confidence, ILEC investment invites additional CLEC entry. The results suggest that incumbents and entrants match each others' investments, and offer little evidence of preemptive behavior or strategic coordination.

These findings recommend that policy makers intent on encouraging construction of the next-generation broadband network should eliminate artificial restrictions on facilities-based entry and ensure that their pricing of incumbent network services sold to entrants take account of the virtuous cycle of investment triggered by this entry. At the same time, the results argue for removing restrictions on incumbent investments, even those traditionally considered to be an effective means to deter competitive entry.

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# I. NEW POLICIES TOWARD LOCAL NETWORK INVESTMENT\

As the 20th century came to a close, countries around the world en masse adopted market forces to discipline their domestic telecommunications industries. They rejected public ownership and administrative regulation–holding these institutions responsible for high prices, poor service and capacity shortages. Facilities-based competition was widely viewed as a superior means to expand capacity and modernize public networks. In the face of increased globalization, policy makers see telecommunications infrastructure as crucial to regional and national economic development, as well as a means to promote universal service goals.

The U.S. was among the leaders in this movement. At both state and federal levels, telecommunications rates and services were decontrolled and service markets of all kinds were opened to competition. The landmark Telecommunications Policy Act of 1996 (TPA96) encouraged entry into local exchange markets by imposing mandatory interconnection, collocation, unbundling of network elements, resale of retail services, reciprocal compensation, number portability and dialing parity. It also removed cross-ownership bans on cable TV and electric power companies which, along with auctioning of new radio spectrum, had the effect of directly expanding the pool of potential wireline and wireless competitors. Years before TPA96, the states first and the FCC later, had adopted "incentive regulation" which provided rate relief that could finance capital expansion. On several occasions, states offered incumbent telephone companies rate relief in exchange for the promise to undertake large network modernization programs.

After lagging behind the U.S. and other regions, Europe has recently moved to open its local telecommunications markets to competition.[1] High as a priority is to relieve the shortage of high-capacity circuits, driving down lease rates and facilitating the spread of internet services. The earliest steps facilitated service-based entry stipulated by the 1987 Green Paper. More recently, directives on interconnection and unbundling have sought to lay the groundwork for infrastructure competition. In contrast with the approach on the continent, the U.K. favored the use of facilities-

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[1] 1993 Directive.

based competition at least during the years immediately following the privatization of British Telecom. The U.K. adopted the long-haul duopoly structure, promoted cable telephony and licensed many wireless access alternatives. Only recently has the U.K. taken measures to facilitate service-based competition by unbundling the local exchange networks.

The 1997 WTO agreement on basic telecommunications services promises to have broad implications for competition in local exchange markets in the 72 signatory countries. The Reference Paper promotes facility-based entry by ensuring nondiscriminatory interconnection, allocation of spectrum, phone numbers and rights of way, promotion of an independent regulatory authority, and the creation of anticompetitive safeguards. Foreign ownership is invited by extending terms to all WTO member countries through MFN and “national treatment” principles.

A common presumption underlying all of these policy initiatives is that competition will result in increased capital investment and accelerated adoption of new technologies. Furthermore, it is generally believed that facility-based competition is a more potent instrument to accomplish these goals that the service-based alternatives. Presumably competitors have better information than regulators as to where, when and how much to invest, and which technologies and services to deploy. The threat of losing business to new facilities-based entrants spurs incumbents to take actions to preserve their market position. Resale of retail services or purchase of unbundled network elements, in contrast, are limited in their ability to exert competition pressure since infrastructure owners control the price and services resellers can offer–though service-based entry is often viewed as a “stepping stone” into facilities-based provision. For their part, the facilities-based newcomers not only contribute to the stock of digital infrastructure, but they also tend to employ the latest techniques to differentiate themselves from existing offerings.

In a 1995 report,[2] the OECD surveyed its 29 member countries on the openness of their telecoms markets and the extent of telecom infrastructure development. Using informal comparisons, the report concluded that countries that permitted “infrastructure competition” realize

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[2] OECD (1995).

the benefits of lower prices, improved quality and variety of services and greater penetration. It also concluded that competition did not harm efforts to promote universal service.

Ideally, we would like to answer a broader question: Does an open entry policy result in more or less efficient timing and location of local exchange investment? We cannot answer this question for several reasons. Assuming that the efficient level of investment can be measured, it could be less than the current level, in which case stimulating investment any more would not serve efficiency. If it was more than current levels, we also cannot be certain that efficiency will be increased by the added investment triggered by an open entry policy. The reason is that, assuming some regulatory distortions will remain, the Theory of the Second Best counsels that achieving the prescribed margin only for investment could harm welfare.

We are left with indicating whether investment increases or decreases as a result of an open entry policy and the subsequent realization of competition. What pattern of investment over time and space should we expect once local exchange markets are opened to competition? One possibility has incumbents quickly matching an entrant's investment so as to halt further loss of customers. An incumbent may act preemptively by building out markets ahead of entry by competitive carriers. Alternatively both types of firms may not respond to recent deployments decisions of their rivals but rather to the cumulative investment made in particular markets.

Opinion on the benefits of infrastructure competition is far from unanimous. Open entry policies that stimulate facilities-based entry can result in duplication of capital investment. From a social perspective, this may be a cost worth bearing in exchange for other performance improvements. Crucial to this calculation, however, is whether competition price and services reduces the returns on these sunk investments to the point where incumbents choose not to invest. A reaction to this fear is the provision in TPA96 that limits the obligations of incumbents to open their networks in the case of provision of advanced services.[3] It may be that many telecom markets

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[3] These include the 1983 amendments to the Communications Act, and Section 706 of the 1996 Telecom Act. A number of states have struck infrastructure bargains with companies where rate liberalization is exchanged for promises to make advanced infrastructure investment.

exhibit natural monopoly characteristics in which case competition would only raise overall industry costs. Alternatively, opening a market may be an empty gesture if dominant incumbent can summarily fend off potential competitors with the threat of fierce post-entry competition, or just drive them to adopt less-threatening service-based strategies. It may respond to the competitive threat by alterning its investment strategy but by cutting price and boosting services. Consumers will, of course, derive short-run benefits from this form of competition but there will be little in the way of durable investment in digital infrastructure.

Missing from this debate is an understanding of how open entry policies affect industry capital investment and technology adoption. What is needed is an empirical test comparing investment under an open-entry policy and under the counterfactual of continued regulatory barriers. This is a huge gap considering the theoretical and empirical support for other major deregulatory initiatives in this area, namely privatization and incentive regulation. There is a large literature documenting superior performance of private ownership over public ownership. There is also a literature drawing out the implications for price, service quality and investment for price caps and other incentive mechanisms, plus an extensive literature condeming rate of return regulation.

To rectify this gap, this paper examines the deployment of one particular new local exchange technology: urban fiber rings in the U.S. Both incumbents and entrants deployed similar facilities that at thie time represented the most advanced networks serving large business customers. Entry of this kind has not been tightly regulated but rather occurred as a product of technical advances. We empirically examine the temporal patterns of incumbent and entrant investment decisions. Our aim is to identify the impact of facilities-based entry (made possible by policies of open entry) on incumbent investment, and to identify strategic interaction that results in more or less investment.

We find that entry tends to stimulate incumbent deployment of fiber rings in the same cities, rather than simply displacing incumbent investment. The reverse also holds true to an extent: incumbent investment triggers entry though with a delay. The result is a positive feedback loop between incumbent and entrant investment.

Open entry policy that, besides the first-order benefits of competition (e.g., lower price, lower cost, better service quality and variety), triggers a virtuous cycle of entry and investment. In practice these implies relaxation of both restrictions on incumbent investment (especially in response to entry) as well as removal of artificial barriers to facilities-based entry
Moreover, it cautions against financial inducements favoring service-based entry relative to facilities-based competition (though the effect of service-based competition remains to be examined).

The next section goes into some detail about the theoretical underpinnings of the relationship between open entry and durable capital investment, and what is known empirically about this relationship. The reader may want to skip immediately to the subsequent section that describes the empirical modeling, followed by a section with estimation results and their interpretation. The paper concludes with a discussion of the policy implications and possible avenues for extension.

## II. OPEN ENTRY AND INFRASTRUCTURE INVESTMENT

A useful model of that would guide specification of an empirical model would answer the question: What does economic theory predict about the timing and location of durable investment and adoption of new technology by both incumbents and entrants when markets are opened to competition? In addition, What empirical implications can be drawn from related studies regarding the likely impact of open entry policy on local exchange investment and regarding the incidence of facilities-based entry?

The application in this paper has aspects of both temporal and spatial competition. We will concentrate on the temporal interaction of incumbents and entrants, reserving treatment of the spatial aspects for subsequent research. We also do not analyze service-based competition such as resale, focusing instead on facilities-based competition. Finally, open entry has implications for other forms of competition besides infrastructure deployment. Incumbents and entrants also compete on price, service quality and reliability, new service introductions, and so on. We do not examine these aspects directly so the open entry policy may register impacts in other ways.

### A. Theoretical Models of Investment

Because of the small numbers of competitors involved in these markets, I look to strategic models of incumbent-entrant interaction for guidance. To begin with there are several simple explanations for the temporal and spatial pattern of investment by incumbents and entrants. Note that entry and network expansion are disequilibrium phenomena. Unexpected demand growth and technical change could trigger both kinds of investment. In this view entry occurs because entrants experience lower costs than what it costs incumbents to expand.

This last conclusion may change, however, when incumbents can use investment strategically. Dixit (1981) showed how an incumbent could benefit from investing in more sunk capacity when threatened by entry. The incumbent will invest more than it would under a simultaneous-move oligopoly, but this need not be more than its investment when protected from competition altogether.

Models with a more explicit dynamic structure allow for strategic use of investment to deter entry or exclude rivals. Preemptive investment can secure markets for early investors. Borrowing from the literature on patent races, we would expect to see incumbents or entrants investing first in new digital networks depending on who has more to gain. Gilbert and Newbery (1979) argue that an incumbent will always have a stronger incentive because it risks losing its monopoly rents. Arrow (1964) and Reinganum (1983) conclude that timing will be the reverse because a monopolist is disinclined to replace itself through the innovation.[4]

These models all find a first mover advantage–they merely differ on which firm has the strongest inventive to deploy. Alternatively, a second mover may have an advantage when it benefits from market information revealed only through an earlier deployment. A second mover can tailor its investment decisions to information about realized demand for advanced services and the best location of the new networks generated by the first mover. The incentive to learn from a rival's previous experience must be balanced against the disadvantages of arriving late to market, in particular, the larger customer base of the first mover.

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[4] Lerner (1997) finds empirical evidence in favor of this last hypothesis in the case of “entry” in the hard disk drive industry.

Incumbents have an alternative reason to invest second, to predate against recent entrants. The pattern that should emerge from predation would have incumbents invest immediately after entry in the same geographic markets. Missing from this story is any form of regulation, before or after entry, which is at variance with the reality of these markets.

Spatial models of competition offer an abundance of implications for where fiber rings will be deployed–in a sense too many possibilities. Tendencies toward minimum differentiation occur *when price competition among rivals is mild or nonexistent, predicting that advanced infrastructure projects will tend to cluster in the same areas. When price or quality competition is fierce, in contrast, firms will tend to seek out markets not currently occupied by rivals to minimize the extent of contact. Along these lines Prescott and Vischer (1979) find a tendency toward equal spacing of entrants in a model of sequential entry into a linear market.

The many different hypotheses regarding the timing and location of investment are arrayed in Table 1 for both incumbents and entrants.

**Table 1: Theoretical Predictions for Investment Timing and Location by Incumbent and Entrants**

| | **INCUMBENT** | **ENTRANT** |
|---|---|---|
| **TIMING** | < Increased investment to deter entry threats<br>< Increased post-entry investment to exclude entrant | < Enter after initial investment to benefit from market information<br>< Enter before incumbent to take full market |
| **LOCATION** | < Fill open niches to deter entry<br>< Match early occurrences of entry into incumbent markets with investments that signal ability to compete | < Locate away from (near to) existing competitors if price competition is strong (weak) |

### A. Empirical Evidence

Surprisingly little is known empirically about the pattern of investment in markets characterized by competition between incumbents and entrants. Geroski (1991) surveyed the empirical literature on entry and concludes that support for many of the theoretical hypotheses about entry is lacking or contradictory. Among his stylized facts is the observation that incumbents do not uniformly take preemptive actions, in either price or nonprice terms.

Besides the fact that many of the early empirical studies of entry were not disaggregated to the firm level, these results need to be taken with caution because the data are not the out come of some natural experiment. In those cases where formerly closed markets are opened to competition, we have the opportunity to correct this. Unfortunately, there is not much known about those cases. In a survey of empirical predictions of deregulated industries, Winston (1993) has little to report in terms of investment effects. Instead most studies examine how liberalized rate making affects capital investment and new technology adoption decisions.[5] In reality, open entry policies tend to be accompanied by other regulatory reforms that make it difficult to isolate the incremental consequences of open entry.[6]

Caution should be exercised when interpreting the results of these studies. First, there is no guarantee that entry will, in fact, materialize once regulatory barriers are eliminated. Further, a reduction in entry barriers is often accompanied by rate liberalization, confounding the effects of these two deregulatory policies. Indeed increased investment (and decreased entry) may be stimulated by the incumbent's ratemaking flexibility.

Nevertheless, there are several studies of telecommunications sector that begin to get at competition's effect on the investment decision. Greenstein, McMaster and Spiller (1995) include several independent variables for state entry. Estimates of their coefficients leads to mixed conclusions, however. Allowance of competitive access providers has no statistically significant

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[5] Taylor, Zarkadas, Zona (1992) and Greenstein, McMaster and Spiller (1995).

[6] An exception is some casual evidence offered by Meyer and Strong (1992) on airline deregulation's effect on aircraft purchasing behavior.

effect while permission for intraLATA competition and resale of local exchange services depresses ILEC deployment of fiber. Removal of restrictions on “bypass,” a form of facilities-based competition, encourages fiber investment by the ILEC but this relationship is only weakly significant. Using country-level ITU data from the 1986-95 period, Ros (1999) finds that opening of local, long distance or international telephone service markets has a positive but statistically insignificant effect on mainline level and growth rates. In contrast, using a regional subset of the ITU data for the 1984-94 period, Wallsten (1999) finds that the presence of one or more independent cellular telephone carriers results in increased penetration of mainlines, number of payphones and capacity of switching facilities–as well as reducing local call prices. In a cross-national comparison that examines cellular mobile services, Dekimpe, Parker and Sarvary (1998) find that both the initial penetration rate (measured by mobile lines per population) and the rate of diffusion increased with the number of competitive cellular carriers—though the coefficients were not always precisely estimated. While cellular is a specialized local services, its importance as a substitute for landline service is clearly growing.

There has been a number of papers that, like this one, examines entry at the firm level. In a series of papers, Bresnahan and Reiss (1991) examine equilibrium structure of geographically isolated markets. By measuring the relationship between market size and number of firms, they help explain when a market would be monopolized or when additional entry would succeed. They do not explicitly account for investment in their models except to the extent tat entry involves real investment.

In another series of paper, Lieberman (1989b) and his coauthors examine use of investment as a strategic decision by both incumbents and entrants in the chemical processing industries. Using plant level data, Lieberman (1989b) finds that incumbents and entrants in obey similar investment rules; in particular, incumbents do not build excess capacity to deter entry, and in the few cases where they appear to do so, the strategy is not effective. In another study, Lieberman finds that incumbents accelerate their investment after entry—at least in more concentrated chemical processing industries.[7]

In a paper very close in spirit to the current one, Toivanen and Waterson (1999) examine the relationship between duopolist's franchise entry decisions in the U.K. fast food market. They find that entry decisions are responsive not to recent rival entry but to cumulative entry. They also find a preference for "virgin" markets not previously entered by a rival. In the case considered in this paper, in contrast, every market is occupied by an incumbent, though they may not have made an investment as of yet.

## II. EMPIRICAL MODELING

### A. The Case of Urban Fiber Rings

The investment modeled in this paper is construction of an urban fiber ring network by either incumbent local exchange companies (ILECs) or competitive local exchange companies (CLECs). These networks are constructed with high-capacity fiber cables that circulate traffic without switching over a ring architecture.

An urban fiber ring costs about $15 million on average and takes 6-18 months from initial ground breaking to "lighting" the fiber. We exclusively are concerned with deployment of these networks for provision of local network services (and not regional or national trunking). They are most commonly placed in the central business district of a large city, but increasingly they reach out to serve the edges of metropolitan areas. These networks pass facilities of large business users and also connect to one or more ILEC wire centers and interexchange carrier switches. To give them unparalleled reliability, they follow routes different from the public switched network and deploy a second counter-rotating fiber serving as a hot standby.[8]

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[7] Lieberman (1989a).

[8] Transmission protocols employed on fiber rings have evolved over the years, with SONET now the overwhelming choice.

ILECs were the first to deploy fiber networks soon after the use of optical fiber was demonstrated for communications transmissions in the late 1970s. The earliest fiber networks were deployed to supplement or replace ILECs' interoffice networks. On occasion they also ran out "fiber loops" to large customers to gather their traffic. These facilities lacked two essential features of fiber rings: they were not redundant (or self healing) and they did not directly serve end users. Besides fiber rings, ILECs also deployed other network structures designed to provide increased reliability to large business users (which may or may not employ optical fiber). These include alternate central office and alternate route services which offer customers a backup line in case of a network failure. In part, these solutions were motivated by several well-publicized network failures such as the Hinsdale, Illinois central office fire in 1991. None of these services, however, can compare with the 99.99999% reliability offered by fiber ring technology.

Competitive access providers, or CAPs, represented a new entrant into local exchange markets who adopted the fiber ring technology almost exclusively. Formed as specialized, private carriers, these firms attacked the high-capacity business access market and so naturally first appeared in the largest, telecom-intensive cities, such as New York and Chicago. After many single-network outfits sprang up across the country, the CAPs expanded into multiple cities and interconnected their various rings with inter-urban networks. They also began to move into smaller cities and suburbs of larger cities as well as expand their existing networks to enlarge their urban footprint. After entry of independent operations, two waves of acquisition occurred in the CAP industry, the first by cable companies and then more recently by long distance carriers. Eventually these carriers were renamed "Competitive Local Exchange Companies" (CLECs) reflecting the wider range of service offerings they provide.

### A. The Sample

We limit the estimation to the 10-year period 1983-92. The first commercial operation of a CLEC ring was launched in 1984. Rings had been deployed by ILECs earlier but usually for interoffice transport. While CLECs have delivered these services using coaxial cable and microwave networks, all CLECs in our sample deploy fiber rings.

Deployments of rings by both ILECs and CLECs over this period are recorded for 128 U.S. cities. These include the 120 largest U.S. cities based on 1990 population figures, plus an additional 8 cities where one or the other or both deploy a ring.[9] Other than these cities, ILEC and CLEC deployments are extremely scarce over this time period, and as expanding the sample beyond this range runs the risk of biasing the estimates.

Information on deployment of rings was derived from many sources. The early editions of the FCC's "Fiber Deployment Update" was especially informative.[10] So too was the FCC's annual "Infrastructure of the Local Operating Companies" which derives from its ARMIS 43-07 infrastructure database (which dates from 1991). Several regular and occasional consulting reports were also used, the most prominent being Connecticut Research Reports's annual survey of competitive access providers begun in 1984. SEC documents were also useful–especially the ILECs' 10-Ks and the S-1s filed by CLECs going public. Finally, we scoured local and national newspapers, local and regional business press as well as the telecommunications trade press.

The year of first commercial operation of a competitive ring (and of construction start if available) was recorded. Usually only one CLEC begins operating in a city in any given year, but there are a few instances where two CLECs entered the same city in the same year. A maximum of three entries occurred in a city over the sample period.

While it is common knowledge that by 1992 more than three CLEC rings have been deployed in certain large cities, I lacked confirmation on the date of first operation necessary to include these observations in my sample. There are cases where a facilities-based entrant has subsequently exited a market. Usually this happens as a result of merger with another CLEC. In a very few instances, the CLEC went into bankruptcy. This exit was treated as a nonevent, since the

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[9] Many gray areas arise in geographic market definition: twin cities, large suburbs or contiguous population areas. The rule we use is to that a city has a population in excess of 100,000, then it was assigned the ring regardless of its proximity to another population centers. If it is smaller than 100,000 and less than 40 miles away from large city, the ring assigned to the neighboring central city; otherwise it is treated as stand alone ring.

[10] This report, first begun in 1986, is based on a voluntary survey that in early years reported on ILEC ring deployments as well as on CLEC entry.

original company's network assets were sold off to another competitive carrier, either one that was new to that market or had entered it previously.

We also record the affiliation of the CLEC. Often they are wholly or partly owned by cable TV operator, a long distance carrier, an electric power utility, and on rare occasion an out-of-region ILEC.

ILEC deployment of fiber rings is also recorded as of the year for first operation. Because of the variety of network structures ILECs have deployed overtime, we identified each deployment as being one of four possible types. The empirical analysis will be confined to either urban firber rings only, or rings with alternate route/central office networks added. As with CLECs, many cases exist where an ILEC ring is known to exist but we lack a date of first operation. In a few rare instances, ILECs have deployed two network structures in the same year, but never of the same type. We also record the particular ILEC's holding company, most often one of the seven regional Bell holding companies or GTE.

We did not have consistent and comprehensive data on the size of the network deployed by either incumbents or entrants. Some information exists on the fiber miles of both firms, and on the network outlays or the number of buildings entered passed by the networks. But no one variable is available for all firms and all markets and all years.

Figures 1 and 2 provide a time series view of ring deployment by ILECs and CLECs. Figure 1 records the cumulative number of cities each type of carrier has entered over the sample period. Figure 2 shows the cumulative number of fiber rings each deployed. Notice that CLECs were initially behind according to either measure through the mid to late 1980s. They pulled ahead in terms of the total number of networks, but continued to lag slightly in the number of cities entered because multiple CLECs enter the same cities.

Table 2 provides a cross sectional view of these same data. It tabulates the number of cities out of a sample of 128 that each type of carrier has entered. Neither an ILEC nor a CLEC deployed a fiber ring in about half of the cities. In more than a quarter of the cities one but not the other carrier deployed a ring.

**Table 2: Cross Tabulation of Ring Deployment by Markets for ILECs and CLECs (1992)**

| | **No ILEC Ring** | **ILEC Ring** | **Total** |
|---|---|---|---|
| **No CLEC Ring** | 68 | 18 | 86 |
| **CLEC Ring** | 16 | 26 | 42 |
| **Total** | 84 | 44 | 128 |

Taken separately, time series and cross section information fail to reveal the interaction that may have occurred between the two types of firms across time and space. Just looking at, say, cross sectional evidence will suppress any intertemporal dependence of carriers' investment behavior. In particular, they could build networks in the same markets but the data would fail to indicate if one carrier acted as a leader and the other a follower, or whether they built simultaneously. For these reasons I constructed a panel data set on ring deployment to analyze these aspects.

### A. Independent Variables

***Regulatory Variables.*** We attempt to control for entry barriers facing entrants into these local markets, especially those erected by state public utility commissions. During the sample period, incumbents and entrants were regulated differently, and over time regulatory policy went through significant changes. From the beginning, CLECs were lightly regulated–if at all. The FCC treated them as nondominant carriers so they received streamlined rate regulation. For a time they had to report their deployment of interstate circuits but not indicate specific locations. States played a much greater role in CLEC activities. Some states outright banned CLEC provision of local services. This was not the barrier it may seem at first since the FCC asserted jurisdiction over a facility whenever more than 10% of the traffic it carried was interstate. Since most competitive access providers targeted the high-capacity long distance access market, they easily fell into federal jurisdiction. More onerous to some, however, were municipal regulations that limited access to public rights of way, doled out construction permits and sometimes taxed CLEC revenues.

Incumbent carriers, in contrast, were heavily regulated, although that eased considerable in the 1990s. In the early years, some of the principal services in question (e.g., DS3 local access and transport) was not rate regulated but treated on an "individual case basis." Later these services came under special and switched access tariffs, and eventually were liberalized under price caps in 1990. It is fair to say that ILEC regulated rates served as an umbrella holding up prices for competitive entrants into these markets.

In a series of important developments the FCC further aided CLEC entry with its policy of expanded interconnection for special and switched access in 1991 and 1992 respectively, which required physical or virtual collocation. Later the implementation of the TPA96 greatly facilitated competitive entry. In the end there is no bright dividing line between a period of prohibited entry followed by a period of open entry. We choose the sample period in this paper so that regulatory barriers are reasonably uniform yet do not substantially preclude facilities-based entry.

Several indicators of state entry barriers are used.[11] Two of these variables appear to be directly relevant: whether state public utility commission allows entry by competitive access providers (CAP) and whether it allows local bypass facilities (BYPASS). Other regulatory variables indicate whether intraLATA toll competition (INTRA), resale of local exchange services (RESLEX) and operation of shared tenant services are allowed by the commission (STS). None of these restrictions represent an absolute barrier to CLEC entry for reasons given above. Nevertheless, a ban on some forms of entry would tend to diminish the profitability of a competitive carrier operating in a state.

As mentioned, municipal regulation can pose significant barriers to entry. Here we control for its effects using fixed effects for the metropolitan area in which the city is located. Similarly,

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[11] I am grateful to the authors of Greenstein, et. al. (1995) for use of these variables.

federal regulation evolved considerably over the sample period–especially policy toward special access rates–and we control for these changes with yearly fixed effects.

***Demand and Cost Shifters.*** Measures of demand for services made possible by fiber rings usually attempt to capture presence of telecommunications-intensive industries. A popular measure is level of activity of the financial, insurance and real estate (FIRE) sector which includes banking, credit agencies, investment services, insurance carriers and brokers, and real estate agencies. We include an estimate of the gross product of the city's FIRE industry imputed using per capita on gross product of the state FIRE sector along with city and state population figures.

There is some reason to believe that certain construction cost factors affect deployment of fiber rings for both ILECs and CLECs. For instance local wages for construction worker and for communications occupations and property values and property rental rates. Lacking city-level measures at this time, we rely on MSA fixed effects to pick up these cost differences

Summary statistics for the dependent and independent variables used in the analysis are collected in Table 3.

## II. MODEL ESTIMATION AND TESTS

### A. Specification Strategy

I take the latent variable approach in specifying the models to be estimated because the profit associated with deployment of ring by either incumbent or entrant is not directly observable. I only observe the deployment decision itself and from it infer relative profitability of different alternatives open to the firm.

Despite these limitations, I am able to collect a panel dataset that permits analysis of interactions in deployment decisions across both time and market regions. Furthermore, by using firm level data, we have the opportunity to get directly at microeconomics of these markets. In particular, we are able to control for regulations that are specific to the firm. Far more important however, these data hold the promise of understanding firm strategic behavior.

Strategic behavior can be expected given the small numbers of firms who make large, infrequent, sunk investments in these networks. Consequently, the profitability of their deployment decisions depends on rivals' current and past deployment decisions, as well as on their own investments. Of course there is a nonstrategic component of this profitability as with any investment since the resulting revenue stream depends on presence of similar capacity currently deployed in the market.

My focus in this paper is the strategic motivation for investment. Incumbents and entrants alike could see their network deployment decisions as affecting future investment by rivals, and build that into their calculation. Potentially, a firm's current deployment decision will depend on a rival's incentives to make an investment in that period, as would be the case in Nash equilibrium of a one-shot game. To compute their best replies, however, firms would have to have enormous amounts of private information to forecast rival's best responses. Instead, I choose to limit deployment decision to being a function of past deployment history excluding the present period. This yields a model of a sequence of deployment decisions where each firm acts as a Stackelberg follower relative to rivals' and own past investments.

Separate equations are estimated for incumbents and entrants (though we do not analyze them as two simultaneous equations). The presumption is that all ILECs exhibit that same behavior regardless of which market they serve or which regional holding company owns them. More restrictive is the fact that I lump together all entrants even though there are many different CLECs, often entering the same market in direct competition with one another.

The panel structure captures differences in regulation between ILECs and CLECs, as well as across regions and across time. Nevertheless, no account is taken for possible connections between geographic markets as would occur when a carrier deployed a ring in a market in response to deployment in a neighboring market. In effect, I adopt a reduced form specification of (unobserved) carrier profits underlying their deployment decisions. This contrasts with the more structural approach in the tradition of Bresnahan and Reiss (1991) who specify the form of the profit function.

***ILEC specification.*** It is assumed that the likelihood of ILEC deployment is related to the environmental factors discussed above as well as own and rival deployments in the past:

$$\Pr\{\,)\mathrm{A}^{L}_{mt} > 0\} = F(\text{demand and cost conditions in m at t, ILEC and CLEC regulation in m at t, past and current ILEC and CLEC deployment; ILEC parameters}) + \,,^{L}_{mt}$$

Here $)\mathrm{A}^{L}_{mt}$ represents the incremental profit to the ILEC of deploying a ring in market m in year *t* where the base for comparison is it profitability in market *m* as of year *t - 1*. The dependent variable in the estimation of these equations is an indicator of whether the incumbent carrier deployed a ring network in that market in that year. ILECs never build rings in the same market in two consecutive years; the lead times and size of these projects make that an irrational strategy.

I take into account past ILEC and CLEC deployments using dummies for number of cumulative entrants (ENTRY1, ENTRY2) in which case the default is a “virgin” market in terms of ILEC deployment. This allows for the possibility of a nonlinear relationship. Incidence of entry is lagged one or more periods (ELAG1, ELAG2), but never more than three given the shortness of our panel. I also occasionally included cumulative entry lagged one period (ESUM). Finally, $,^{L}_{mt}$ denotes the error term which depends on the form of the discrete choice specification.

***CLEC Specification.*** The specification of the CLEC entry decision exactly parallels the ILEC specification (though with differences in certain variables):

$$\Pr\{\,)\mathrm{A}^{E}_{mt} > 0\} = G(\text{demand and cost conditions in m at t, ILEC and CLEC regulation in m at t, past and current ILEC and CLEC deployment; CLEC parameters}) + \,,^{E}_{mt}$$

Now $)A^{E}_{mt}$ is the entrant's incremental profit derived from deploying a ring in market *m* in year *t*. Its baseline profitability could be zero if it did not have any presence in that market as of year *t-1*. In fact successive deployments are undertaken by different CLECs. Typically they build in different sections of a metropolitan area, but it is not uncommon for them to overbuild one another.

For both ILEC and CLEC specifications, I ignore connections across geographic markets. We would expect lower incremental cost of building a ring when the carrier has completed rings in other markets. Also, the addition of a new market to an existing collection of markets should enhance the service provided customers which, in turn, should be reflected in increased revenue.

### B. Estimation Strategy

For both ILEC and CLEC specification we take as the dependent variable the deployment of an urban fiber ring in each calendar year, 1983-1992. This involves completion of construction and subsequent operation. I also examine the effect of adding alternative local fiber networks (i.e., alternate route and alternate central office networks) to ring networks. As we will see, the results do not differ appreciably between the two dependent variables. In the case of the CLEC model, this may involve two deployments in the same year. Since these are rare events, I feel justified in treating these cases as instances of a single entry.

To accommodate the binary dependent variable for either specification, I estimate a probit model for both ILEC and CLEC deployment. I nevertheless also estimate a linear probability model as a robustness check. Qualitatively, the two specifications produce similar results. In both cases I adopted a random effects specification. In almost all specifications examined, I reject the Hausman test of differences between the random effects and fixed effects specifications.

Estimating these equations can answer several questions. First, how do the various environmental factors–especially firm-specific regulatory policy–affect the deployment decision? Second, how do incumbents respond to the incidence of entry, and how do entrants respond to incumbent deployment decisions? Implicitly the maintained null hypothesis has incumbent and entrant decisions being unaffected by market conditions and exhibiting no strategic interaction with their rivals–as if ILECs and CLECs randomized their deployment of ring networks across markets and across time.[12]

### C. Estimation Results

***Demand and Cost Conditions.*** In the case of demand and cost variables, the ILEC and CLEC equations had roughly the same results so I discuss them together here. The log of population variable, LPOP, consistently entered both equations with a statistically significantly with a positive sign. In contrast, the primary demand shifter, FIRE and its variants, rarely entered significantly or with the anticipated sign. On a few occasions, FIREGROW (five-year trailing growth rate of F.I.R.E. sector imputed to a market) appeared with a positive coefficient that was only marginally-significant.

Rather than attempting to control for cost factors directly (e.g., using wage rates and land values), I introduce MSA fixed effects to pick up variations in cost across markets. They very rarely appeared as significant in the estimations, however. Year fixed effects consistently were positive and highly precisely estimated. They could be capturing time trends in cost as well as other trends such as the usual diffusion pattern and improvements in fiber technology. Also, while the LPOP variable was intended as a demand shifter, it may be controlling for cost since it is highly correlated with population density which is well known to be an important telecommunications cost determinant.

***ILEC Deployment Results.*** Table 4 gives the estimation results for the preferred specification of the ILEC equation. The signs of coefficients on the demand and cost variables were as expected, though they were often not precisely estimated. When non-ring network deployments were added in, there was not much change in sign or magnitudes. Dummies for the identity of the

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[12] An alternative null hypothesis for ILECs would have them deploying the ring networks as a replacement for existing infrastructure, in which case we would expect the deployment to obey a typical time pattern of diffusion of a new technology.

ILEC's regional holding company did not enter significantly (with the possible exception of BellSouth which was known for its aggressive fiber deployment program).

Turning to regulatory variables, we might speculate that CAP will enter positively should foreshadow prospective competition for the ILEC. In fact, CAP did have a positive coefficient but it was usually not precisely estimated.[13] Lagging the regulatory entry barrier to CLECs did not change results appreciably. Finally, because regulation may respond to entry, and not the other way around, I performed a Hausman specification test on that variable. Consistently the test rejected that CAP was endogenous in the ILEC investment equation.

To allow for ILEC response to CLEC entry, I included indicators of cumulative entry (ENTRY1, ENTRY 2) and recent entry (ELAG1, ELAG2) with lags up to two periods. Consistently, none of the cumulative entry variables had a significant effect on ILEC investment; however, the coefficient on the most recent entry event (ELAG1) invariably was positive and precisely estimated. In contrast, entry with a two-year lag (ELAG2) almost never was significant.

Variables indicating both cumulative and recent ILEC investment entered strongly negatively, confirming that ILEC investment in these networks is a rare event that is never followed soon after by another deployment. These variables do not make sense in the specification and therefore were excluded from the final specification.[14]

***CLEC Entry Results.*** Next we turn to the estimation results for CLEC entry equations. Coefficient estimates were qualitatively the same as with ILEC equations for demand and cost variables and for fixed effects. As expected, the coefficient on CAP is positive and highly significant, confirming that open entry policy tends to lead to more entry. A Hausman specification test rejected the hypothesis that this variable is correlated with the error term. Correlation would

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[13] CAP appeared strongly positive when MSA fixed effects included, but washed out when year fixed effects were introduced.

[14] An exception would occur if we made the distinction between urban fiber rings and alternate route networks which could be deployed on separate schedule and exhibit some interaction between the two deployments.

arise if opening markets was merely a state PUC response to threats by potential competitors to enter these markets.

Turning to the deployment variables, we see that the likelihood of entry *reduced* by both cumulative past entry by CLECs and lagged investment by ILECs. In contrast, the likelihood of entry *increases* with the first ring deployed by ILEC, and with the incidence of lagged entry. This pattern of coefficients proved to be robust across several different variations on the specification, including with different lag structures, with different fixed effects and with and without ILEC alternate networks.

We can use coefficient estimates over the time pattern of CLECs' responses to previous deployment of rings to compute the long-run effects of an ILEC deployment. Suppose that in some period an ILEC ring exogenously appears in a market where there had not been one previously. Give the CLEC specification, this event will have both immediate and lagged impacts on the likelihood of CLEC entry. If the ring is deployed in period $t$, then in period $t + 1$ an impact on the likelihood of entry will appear through the INVEST1 coefficient as this is the first ILEC network in this market, and also through the ILAG1 coefficient. Using the linear probability estimates for illustration we measure the net effect to be: -0.116 + 0.173 = 0.057, or a 5.7% *increase* in the likelihood of CLEC entry. There is also a subsequent impact through the ILAG2 coefficient which amounts to a change of -0.205 + 0.173 = -0.032, or a 3.2% decrease in this same likelihood. On net, there is a 2.5% increase in the likelihood of CLEC entry in response to an exogenous ILEC deployment.[15]

## D. Exogeneity Tests

A key question that this paper seeks to address is whether incumbent and entrant investments are conditioned upon one another as would be expected should they behave strategically. Coefficient estimates appear to show a connection in their investment decisions. I seek to go further and statistically test for a causal connection between the two decisions. As a first pass I performed

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[15] I did not find ILEC investment lagged three periods to be statistically different from zero, so the analysis is truncated at two period lags.

Granger causality tests of the hypothesis that ILEC investment "preceded" CLEC entry, and vice versa. In all cases I rejected Granger noncausality thereby supporting the temporal connection of these decisions. This is, however, a limited test of the statistical relationship between these time series, and so went on to test for exogeneity between the investment decisions.

I follow the procedure laid out in Maddala[16] that adopts the Hausman (1979) methodology. For instance, I ran INVEST on the different ENTRY variables from the CLEC specification. I then insert the fitted values (along with observed values) back into the CLEC equation, and tested whether it has a zero coefficient. If the hypothesis is rejected, then we conclude that INVEST is not exogenous or predetermined for ENTRY. Instead, this offers evidence that INVEST "causes" ENTRY. Apparently, there are factors–likely to be unobservable–that statistically determine both of these variables with a lag.

Exogeneity tests of this sort were performed on both equations with the same results: I reject that INVEST is exogenous for ENTRY and that ENTRY is exogenous for INVEST. Note that, because contemporaneous values of rival deployment are not included in either specification, I do not test for within-period strategic interdependence between incumbents and entrants. One implication of the apparent endogeneity in ILEC and CLEC deployment decisions is that the process generating these data is properly modeled as a system of simultaneous equations.

### E. Interpretation of the Results

We found that ILEC deployment responds to recent entry rather quickly, but that cumulative entry has no effect. One interpretation of this result is that it is revealing a predatory response to entry by the incumbent. Observationally equivalent, and just as plausible, is the interpretation of this response in terms of "profit signaling." In this story, upon deployment, the entrant signals to the incumbent (and vice versa) that it considers the market a worthwhile investment. If the laggard has poorer information about the profit of a market, this is a rational strategy.

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[16] See Maddala (1988, pp 325-333).

We also found that CLEC entry tended to be discouraged by cumulative past, but encouraged by lagged entry events and by first ring deployment by ILEC (though not by recent ILEC investment). One interpretation is that, once again, CLECs respond to ILEC investments as a signal of profitability. Now however the market may soon reach saturation.

There also seems to be a "bandwagon" effect occurring among entrants, where they pile on once one ventures into a market. Profit signaling may again be at the source of these decisions. Setting aside for the moment the fact that I have lumped all CLECs together for estimation purposes, it is possible that ILEC ring deployment and another CLEC's entry likely conveys different information about that particular market. Presumably the profitability of entry by a new firm will be more highly correlated by a CLEC's assessment of profitability than an ILEC's assessment as revealed in their decisions to invest.

## III. POLICY IMPLICATIONS AND EXTENSIONS

We have modeled deployment of a new capital-intensive telecommunications technology, paying particular attention to the temporal and spatial interaction when facilities-based carriers enter formerly monopolized markets. The findings from the empirical analysis recommend that policy makers intent on encouraging construction of the next-generation broadband network should eliminate artificial restrictions on facilities-based entry and ensure that their pricing of incumbent network services sold to entrants take account of the virtuous cycle of investment triggered by this entry. At the same time, the results argue for removing restrictions on incumbent investments, even those traditionally considered to be an effective means to deter competitive entry.

In principle, facilities of this sort should be built whenever their benefits to telecommunications users exceed the long-run average incremental cost of the investment. In addition, the least-cost builder and operator of facilities should construct and operate the network, respectively. The empirical results do not allow us to conclude that competition drives these markets towards efficiency. We can merely note that entry appears to have a stimulating effect on both incumbent investment and subsequent entry.[17] It is hoped, nevertheless, that the patterns uncovered in this study could guide policy toward other kinds of infrastructure development, such as the ongoing deployment of broadband access to residential customers.

Before undertaking such an ambitious task, however, we should make a more complete assessment of the limitations of the results for policy prescriptions. First of all, I focused exclusively on facilities-based competition, excluding all instances of service-based entry. This is not a sizable omission over the chosen sample period; significant resale, UNE competition and line sharing had to wait for implementation of TPA96. In any event we lack the evidence as to whether facilities-based competition is more or less effective than the service-based alternatives in stimulating deployment of digital infrastructure.

Several obvious extensions of this research have been mentioned in passing. Among the highest priorities is the need to distinguish the many different CLECs. A simple way to distinguish the CLECs would be to introduce a separate equation for each CLEC. Since there are literally dozens of CLECs that entered over the sample period, this would eat up degrees of freedom and may make sharp conclusions difficult. On the other hand, it does have the advantage of controlling for potential entrants by tracking CLECs that did not enter any market in the early periods.

Another exercise that could lead to a better understanding of incumbent-entrant interaction would be to treat ILEC and CLEC investment as a system of simultaneous equations. This would be an innovation over previous empirical studies of entry behavior. In the process, it might be possible to take a more structural approach by specifying the underlying profit function as done, for example in Toivanen and Waterson (1999).

For both entrants and incumbents it would be worthwhile to take into account the spatial relationship among their various ring deployments. In particular, the likelihood of deployment by either firm may increase with the number of installed base of networks within a certain distance of a

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[17] Of course this neglects the many other beneficial effects that carrier competition delivers such as lower prices, improved service quality, and higher productivity.

market, or within the same state.  Casual observation seems to suggest that ILECs more often undertake programs that deploy networks in many markets simultaneously, whereas typically CLECs enter markets serially. There could be cost savings from having built networks in the vicinity, plus customers of the ILEC or CLEC may benefit when their carrier has a more widespread coverage.  For instance, a corporation could link up its far flung offices while having the benefits of one-stop shopping.

A related issue that was not addressed in this paper was the proper classification of entrants. Some of the CLECs entered the local network business at the very beginning of the 10-year sample period.  By the end of this time, they typically have networks running in many cities.  They are likely to behave differently than a de novo entrant.  We would like to check for the possibility that, at some point in time, early entrants begin to behave like incumbents at least relative to subsequent entrants.  And if the sample period was extended, we would also find instances of ILECs building or acquiring networks for the first time out side their serving territory.

There are also important difference among the firms deploying these networks that may affect their investment behavior.  CLECs are often owned by cable TV companies or long distance carriers, and in a few cases, by electric power utilities.  The nature of the parent’s core business may affect its cost to entry and the preferred location of its network deployments.  It would be especially interesting to isolate the behavior of CLECs owned by out-of-region ILECs.  This innovation would require us to track investment activity beyond each city-year cell in the panel as done here, and instead carry along information on the characteristics of those firms.

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Figure 1: Cumulative Cities Deployed Over Time

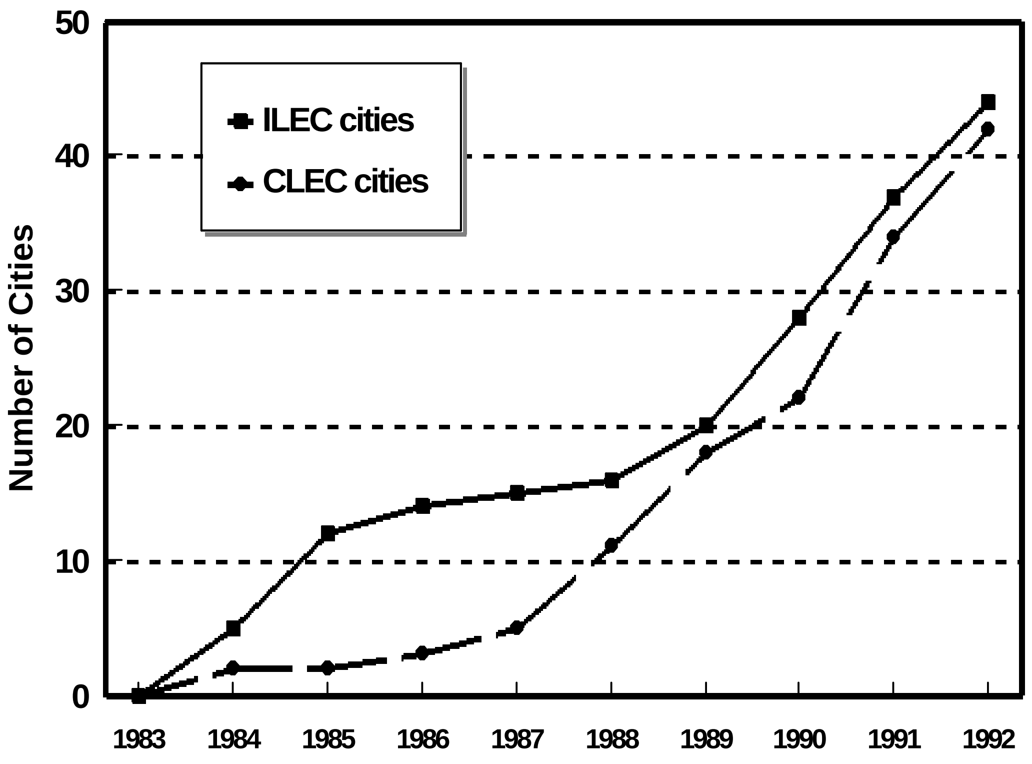
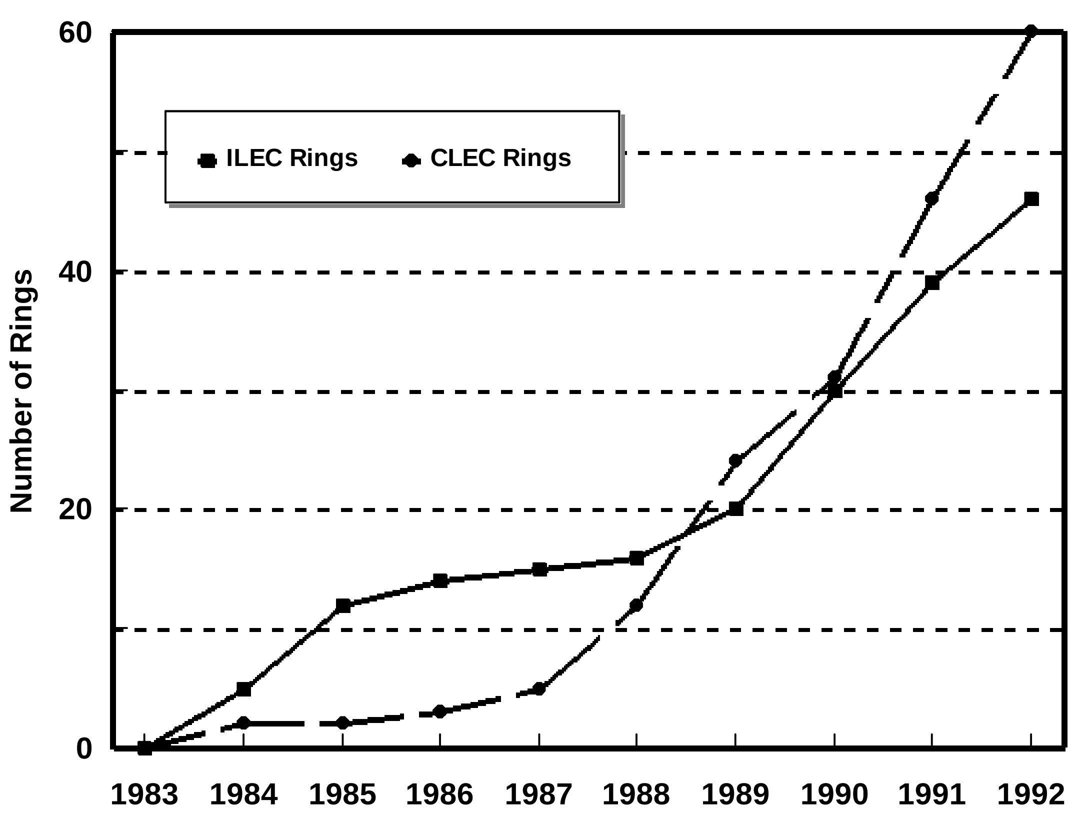


Figure 2: Cumulative Rings Deployed Over Time



# Table 3: Summary Statistics

| Variable | Description | Min | Max | Mean | Std Dev |
|---|---|---|---|---|---|
| **CITYRANK** | Population rank of city, 1990 | 1 | 314 | | |
| **STATE** | Code for state in alphabetical order | 1 | 50 | | |
| **YEAR** | Calendar year | 1983 | 1992 | | |
| **FIREGSP** | Gross state product of F.I.R.E. sector (M 1992 $) | 1,994 | 195,930 | 52,652.59 | 57,684.21 |
| **FIREGROW** | Five-year growth rate of city F.I.R.E. sector (%) | -30.91 | 112.24 | 6.85 | 13.58 |
| **CITYPOP** | Population of city, 000s, 1990 | 72 | 7,323 | 437 | 752 |
| **STATEPOP** | Population of state, 000s, 1990 | 488 | 30,854 | 10,780 | 8,942 |
| **LCITYPOP** | Log of 1990 city population in 000,000s | -0.33 | 4.29 | 1.08 | 0.73 |
| **LEC** | Code for local exchange company | 1 | 28 | | |
| **HOLDCO** | Code for holding company | 1 | 13 | | |
| **MSA** | Code for metropolitan area | 1 | 545 | | |
| **BYPASS** | Indicator of state PUC allowance of bypass | 0 | 1 | 0.39 | 0.49 |
| **CAP** | Indicator of state PUC allowance of CAPs | 0 | 1 | 0.33 | 0.47 |
| **INTRA** | Indicator of intraLATA competition | 0 | 1 | 0.48 | 0.50 |
| **RESLEX** | Indicator of allowance local exchange resale | 0 | 1 | 0.11 | 0.31 |
| **STS** | Indicator of shared tenant services | 0 | 1 | 0.67 | 0.47 |
| **ERINGS** | Number of entry events, city and year | 0 | 2 | 0.05 | 0.24 |
| **IRINGS0** | Number of ILEC alternate networks, city and year | 0 | 1 | 0.01 | 0.10 |
| **IRINGS1** | Number of ILEC fiber rings, city and year | 0 | 1 | 0.04 | 0.19 |
| **ESUM** | Cumulative entry events | 0 | 3 | 0.14 | 0.45 |
| **ISUM1** | Cumulative ILEC rings | 0 | 2 | 0.15 | 0.37 |
| **ISUM01** | Cumulative ILEC rings and alternate routes | 0 | 2 | 0.18 | 0.44 |

## Table 4: ILEC Deployment Estimations

| | **Probit** | **Probit** | **Linear** | **Linear** |
|---|---|---|---|---|
| **Dependent Variable:** | **IRINGS** | **IRINGS+** | **IRINGS** | **IRINGS+** |
| **CONSTANT** | - 8.529 *** | - 8.737 *** | -0.043 | -0.069 |
| | ( 0.741) | (0.726) | (0.042) | (0.052) |
| **LPOP** | 0.390 *** | 0.463 *** | 0.033 *** | 0.046 *** |
| | ( 0.149) | (0.154) | (0.011) | (0.014) |
| **FIREGROW** | - 1.658 | 1.018 | 0.081 | 0.073 |
| | ( 1.176) | (1.143) | (0.064) | (0.078) |
| **CAP** | 0.184 | 0.059 | 0.025 | 0.023 |
| | (0.322) | (0.318) | (0.022) | (0.027) |
| **ENTRY1** | - 0.523 | - 0.891 * | -0.042 | -0.061 |
| | ( 0.413) | ( 0.476) | (0.035) | (0.046) |
| **ENTRY2** | -0.58 | -1.372 | 0.002 | -0.015 |
| | ( 0.604) | (0.855) | (0.059) | (0.073) |
| **ELAG1** | 0.650 ** | 1.032 *** | 0.120 *** | 0.123 *** |
| | (0.321) | (0.419) | (0.035) | (0.043) |
| **ELAG2** | 0.055 | 0.533 | 0.012 | 0.05 |
| | (0.363) | (0.515) | (0.039) | (0.048) |
| **Log likelihood:** | -135.43 | -150.88 | | |
| **$R^2$** | | | 0.1002 | 0.1056 |

Note: Statistical significance indicated by: * = 10%, ** = 5%, *** = 1%; probit coefficients have not been rescaled as derivatives of likelihood of deployment.; all MSA and YEAR effects have been suppressed.

## Table 5: CLEC Entry Estimations

| | **Probit** | **Linear** |
|---|---:|---:|
| **Dependent Variable:** | **ERINGS** | **ERINGS** |
| **CONSTANT** | -14.782 *** | -0.167 *** |
| | ( 1.599) | (0.052) |
| **LPOP** | 1.629 *** | 0.068 *** |
| | ( 0.306) | (0.015) |
| **FIREGROW** | - 1.393 | 0.051 |
| | ( 1.886) | (0.080) |
| **CAP** | 1.321 *** | 0.110 *** |
| | (0.514) | (0.028) |
| **ENTRY1** | - 3.298 *** | - 0.150 *** |
| | (0.588) | (0.045) |
| **ENTRY2** | -4.731 *** | - 0.380 *** |
| | (1.010) | (0.078) |
| **ELAG1** | 1.435 *** | 0.087 ** |
| | (0.472) | (0.044) |
| **ELAG2** | -1.809 *** | -0.047 |
| | (0.612) | (0.049) |
| **INVEST1** | 1.366 ** | 0.173 *** |
| | (0.690) | (0.041) |
| **INVEST2** | 2.557 | 0.399 *** |
| | (1.710) | (0.145) |
| **ILAG1** | -1.277 | - 0.116 ** |
| | (0.798) | (0.049) |
| **ILAG2** | -2.731 *** | - 0.205 *** |
| | (0.964) | (0.052) |
| **Log likelihood:** | -91.57 | |
| **$R^2$** | | 0.1719 |

Note: Statistical significance indicated by: * = 10%, ** = 5%, *** = 1%; probit coefficients have not been rescaled as derivatives of likelihood of deployment.; all MSA and YEAR effects have been suppressed.