An Econometric Analysis of the Factors that Influence the Deployment of Advanced Telecommunications Services

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Abstract

This study examines the decisions of all incumbent local exchange companies (ILECs) in the United States to deploy advanced telecommunications services within each of their wire center serving areas. The advanced telecommunications services examined are packet switching, digital signal level (DS) transport, and synchronous optical network (SONET) technologies. The study is unique in its level of granularity and the set of economic determinants controlled for in the econometric analysis. By controlling for a host of firm, marketing, demand and regulatory factors, the study suggests that both Schumpeter and Schmookler were correct in that large providers are more likely to innovate and that demand matters. More importantly, by controlling for competition, the study suggests that most forms of incentive regulation - particularly indexed price caps - are not conducive to innovation as compared to rate base rate-of -return regulation (RBROR)

I. INTRODUCTION

The general question addressed in this inquiry is: Which economic factors have the greatest impact on technological innovation? The particular focus of this study is an assessment of the primary economic determinants underlying the adoption[2] of technological innovations in the telecommunications industry since the passage of the Telecommunications Act of 1996. These economic determinants include market structure (including concentration or some measure of the level of competition), firm size, market demographics (business vs residential characteristics), and - because it is the telecommunications industry - regulation.

[1] Financial support from the Russell Sage Foundation is gratefully acknowledged.

[2] The value of an innovation to society is only realized when it has been adopted or diffused. "It is diffusion rather than invention or innovation that ultimately determines the pace of economic growth and the rate of change of productivity." [Hall and Kahn (2003, 3)]

Technological innovation is a form of technological change. According to Stoneman (2002, 4):

> Technological change means changes in the goods and services produced and the means by which they are produced. Technological advances are changes where the new in some sense is considered superior to the old. Technological advances in the nature and types of products produced are product innovations. Technological advances in the techniques used in production, whether they relate to the type of machinery employed, the layout of the factory, the raw material and intermediate inputs employed or the management methods used would all be considered as process innovations.

The key to economic growth is technical creativity or technological innovation.[3] Yet, despite the growing recognition of its importance, economists do not understand the interplay of economic forces underlying technological change. "R&D is important to economic growth, but just how important is a question economists are not yet fully able to answer."[4] Moreover, there has been no empirical study proving that technology has been the engine of modern-day growth.[5] In other words, the economic profession is looking through a glass darkly. This study of the relationship between innovation and market structure is an attempt to shed some light on this complex subject.

Since the study will focus on the telecommunications market and its unique characteristics, the observations obtained here will have singular significance to the interpretation and worth of the Telecommunications Act of 1996 and the setting of future telecommunications policy.

Why is this Issue Interesting?

One of the more controversial issues in economics is whether competition or monopoly is more favorable to technological progress or innovation. The telecommunications market following the Telecom Act of 1996 provides a unique market to observe the nature of competition and its effect on technical innovation. As a result of the Telecom Act of 1996, ILECs are monopolists in some markets and face competition in others. Given these dual roles, how will the incumbent respond to making advanced technological services available? Will it make those advanced services available in their competitive markets and not in there monopoly markets as some have argued? Or will it provide those services only in its more monopolistic markets where it can control the price? Which are the most significant factors driving the decision to employ technological innovation? These are some of the policy and strategy issues that continue to affect the implementation of the Telecommunications Act after nearly seven years and underlie the recent, embittered Triennial Review.

Background

[3] This is the conclusion reached by Mokyr (1990) in his study of the economic history of technological change from the classical age (around 500 B.C.) to the early twentieth century.

[4] Boskin and Lau (1996, 17)

[5] Grossman and Helpman (1994)

Much of the economic literature and many of the empirical studies have been devoted to understanding the relationship between innovation and market structure – in particular, the degree of concentration and firm size. In general this has stemmed from various interpretations of the Schumpeter (1942) argument[6] that innovation is more likely to occur in concentrated markets than in purely competitive markets. According to Cohen and Levin (1989), Schumpeter's assertions have inspired the second largest body of empirical literature in the field of industrial organization. Most of this literature is devoted to testing two hypotheses associated with Schumpeter:

(1) innovation increases more than proportionately with firm size,
(2) innovation increases with market concentration.

The economic profession still has not reached consensus on this subject otherwise there would be no need to further investigate the issue nor would there have been any justification for producing such a large body of empirical studies. However, the problem with the various studies and the subsequent interpretations is: (1) there seem to be little consensus amongst economists as to exactly what Schumpeter meant; (2) the use of R&D expenditures (or variations on direct expenditures by examining scientific or engineering levels of employment) as a common measure of innovation still begs the question as to the relationship between innovation and market structure. Even more dismaying, is there appears to have been even less focus on the degree of innovation and diffusion and their correlation with market structure.

Schumpeter himself seems to be saying that there is more to competition than merely focusing on price, which he viewed as static competition of existing products. He seems to be advancing an argument that demands focusing on the dynamics of competitive forces, which includes innovation or technical progress in the context of market structure [see Martin (1993, 351-352)].

Cohen and Levin (1989) show, in their review of the literature on innovation, that firm size and concentration may not be the primary independent variables in determining the degree of innovation. Some studies suggest that interaction between firms, firm size and other attributes come into play. These other attributes include demand, technological opportunity, density of the market - i.e., urban versus rural - or even firm characteristics.

What Has Been Learned About the Issue?

More and more is becoming known about the nature of innovation in the telecommunications market post-Telecom Act of 1996. I have discussed the general background on the subject above. But the telecommunications market is unique, as it does not really fit any of the basic paradigms proffered by much of the existing body of empirical literature on market structure and technological innovation. The uniqueness of the telecommunications industry stems from the important role regulation has played in its history. One cannot discuss innovation or competition without also discussing regulation. The period of this study also coincides with a move amongst federal and state regulatory commissions to a less rigid form of regulation. Some of the studies that will be reviewed below have tried to address these issues of competition and regulation - usually separately and occasionally

[6] The Schumpeter hypotheses will be discussed in Chapter 2.

simultaneously. Nonetheless Sappington (2002, 81) believes, "Future empirical work must distinguish more clearly between the effects of incentive regulation and the effects of competition."

Past industrial organization studies have found some support for the belief that competition has a positive effect on innovation. However, as mentioned above, the effect of firm size and market structure is still being debated although there are few such studies focused primarily on the telecommunications market. There are additional studies that show that the type of regulation faced by telecommunications providers has an impact on innovation. Despite the insights gained from all of these studies, they are still somewhat limited. The unit of observation of past studies has been the State or the major telecommunications firms. The unit of observation in this study is the wire center serving area. This more granular approach allows for far more heterogeneity in the characteristics of market structure - firm size, firm ownership, demand, concentration - in addition to competition and regulation. Thus, this study addresses the particular issues unique to the telecommunications industry while also addressing the more general issues of market structure and innovation of interest in the economics profession.

II. LITERATURE REVIEW

Any study of the economics of technological innovation and market structure must begin with a discussion of Schumpeter's thinking. Kamien and Schwartz (1982, 22), reflecting a broad interpretation of this work by the economic community, have coalesced his thinking on technological innovation and market structure into two tenets termed the *Schumpeterian hypotheses*:[7]

(1) There is a positive relationship between innovation and monopoly power with the concomitant above normal profits.
(2) Large firms are more than proportionately more innovative than small firms.

But even though these hypotheses reflect the general thinking of the economic community, there is still some debate on the correct interpretation of Schumpeter's thinking on the nature and causes of technological innovation. But, however one interprets the writings of Schumpeter, all are clear that he envisioned a link between market power (or market structure) and innovation. What is not clear are the nature of that link and the role of monopoly (or market structure). According to Scherer (1992, p 1421):

> The only simple conclusion stemming from this and much other theoretical research stimulated by Schumpeter's original conjectures is that the links between market structure, innovation, and economic welfare are extremely complex.

MARKET POWER AND INNOVATION

Cohen (1995) points-out that Schumpeter believed that firms required the expectation of some degree of market power if they were to undertake the riskiness associated with

[7] Kamien and Schwartz view these two hypotheses as "independent because possession on monopoly power does not imply large size, except in relative terms, …, large firm size does not imply monopoly power."

innovative activity. Scherer (1967) established that there was an "inverted U" relationship between innovation and market concentration. This confirms Loury's (1979) argument that the optimum concentration level is intermediate between pure monopoly and perfect competition

Farber (1981), Jaffe (1988) ,Boone and an Dijk (1998), Crépon et al (1998) , Blundell et al (1999), Aghion, Harris, Howitt and Vickers (2001) and Sutton (1998) found that market structure had a significantly positive effect on innovative activity, but that it is complex and non-linear

III. TECHNOLOGIES, REGULATION, AND DATA

A. TECHNOLOGIES[8]

The primary focus of FCC studies on the availability of advanced telecommunications services tend to focus on DSL-type services.[9] Clearly this is important if customers are to benefit from the Internet, but there are other advanced telecommunications services (ATS), which, while not as well known, will be crucial to the backbone network of the Internet as well as the facility with which industries conduct business. It is these types of services that form the basis of the growth in productivity. The FCC Third Report (at 9) defines advanced telecommunications services as:

> … consistent with prior Reports, we will use the terms "advanced telecommunications capability" and "advanced services" to describe services and facilities with an upstream (customer-to-provider) and downstream (provider-to-customer) transmission speed of more than 200 kbps in this Report. We will use the term "high-speed" to describe services with over 200 kbps capability in at least one direction. Thus, high-speed is a larger category than advanced telecommunications, …

In this study we will focus on those factors effecting the adoption of a subset of those ATS - digital signal level (DS) technologies, packet switching, frame relay, asynchronous transfer mode, and synchronous optical network (SONET) - or optical carrier (OC). Packet switching will subsume frame relay and ATM.

Frame Relay and ATM are the two principal broadband technologies used by large business customers. The majority of these markets (approximately two-thirds) is provided by AT&T, WorldCom, and Sprint. The other one-third is made-up of the RBOCs and CLECs. This market is growing and an expected $50 billion in network investment will be needed over the next five years.[10]

B. REGULATION[11]

[8] The source for the material in this section came from Budde (2003), Dodd (2002), Horak (2002), and Newton (1998).

[9] Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, CC Docket 98-146 (2002) *(Third Report)*

[10] See Comments of Verizon, *Appropriate Framework for Broadband Access to the Internet over Wireline Facilities*, CC Docket No. 02-33 (May 3, 2002), Exhibit A (Broadband Fact Report).

[11] For additional perspective on regulation and deregulation, see Vogelsang and Mitchell (1997), Lafront and Tirole (2000), and Crew and Kleindorfer (2002).

One of the key economic determinants to be examined is the effect of regulation on the deployment of advanced services. Prior to the mid-1980s, all carriers were under rate base rate-of-return (RBROR) regulation. During the 80s a concensus was reached in the economic community that RBROR regulation was inefficient[12]. Since then, there have been ongoing discussion and proposals of regulatory forms that could produce the same welfare enhancing effects of competition. More specifically, regulatory reforms were devised that had as their objective a reduction in prices, the lowering of operator costs, and providing incentives for infrastructure investment.

The FCC price cap plan for AT&T (1989) is usually referred to as the beginning of incentive regulation in the United States. However, state commissions had already begun experimenting with alternative regulatory forms. New York created an earning-sharing plan for New York Telephone and Rochester Telephone in 1987. Since then, there have been many different alternative regulatory plans developed at the state level. What follows is a summary description of the primary regulatory forms developed at the state level[13]. One of the purposes of this study is to identify the impact that these various forms of regulation have on the rollout of Advanced Telecommunications Services.

Rate Base Rate-of-Return

This is the form of regulation that has traditional governed LECs. Operating costs are determined - usually on an embedded basis and rates for services are set to generate revenues that would cover these costs plus a commission-determined fair rate of return on investments.

Banded Rate-of-Return

Similar in construction to rate-of-return regulation, this form of regulation, however, specifies range (or band) of allowed returns. Prices are initially set to generate earnings that would fall at the mid-point of the range. Any earnings that exceed the maximum limit are returned to the consumers. If earnings fall below the minimum, new prices are devised so that projected earnings will fall within the prescribed range.

Rate Case Moratoria

This is probably the simplest form of alternative regulation. In its simplest form, these are agreements to suspend investigation of the regulated firm's earnings. This can be viewed as an initial form of alternative regulation and is usually only for a short period of time (about two years) prior to moving to one of the other forms of incentive regulation.

Earnings Sharing

The basis for setting rates is unclear. It could still be RBROR. The difference is that the ILEC is allowed to keep all or a percentage of earnings above a specified return on investment. The variation in plans comes in how earnings will be shared. As an example, a

[12] See also Crew and Kleindorfer (1996).

[13] Information for this section came from Sappington and Weisman (1996), Abel and Clements (1998), Sappington (2002).

firms is allowed to keep all earnings between 8% and 12%. Earnings between 12% and 14% are shared in some manner with consumers - usually fifty-fifty. Earnings above 14% are considered an excess return and are passed on to the consumer. Earnings below 8% are also shared with the consumer in higher prices.

There are numerous variations on earnings sharing plans. Sharing could be reversed so that the first segment above the expected range of returns is shared, but thereafter, the firm retains all earnings. Or there could gradual level of sharing.

Revenue Sharing

Revenue sharing is similar to earnings sharing with the difference being the focus is on revenues rather than earnings. Advocates of these plans consider them more of an incentive to reduce costs than earnings sharing.

Rate Freeze

A rate freeze is an agreement not to raise or lower prices for a specified period of time. This is a simple way of promoting incentive regulation and encouraging firms to reduce costs since during the period of its implementation, the firm keeps all cost savings. A rate freeze is often accompanied by a rate case moratorium.

Non-indexed Price Cap

A price cap set a ceiling on rates for a set of services. This can be similar to a rate freeze except that prices are allowed to decrease. The variation comes in how permanent is the price ceiling. Some price caps are allowed to increase by a specified percentage every year or in any twelve-month period. Another variation allows ceilings to increase in accordance with inflation. The inflation index is usually the percentage change in the GDPPI for the previous year or an average over the previous three or so years.

Indexed Price Cap

Indexed price caps is probably the best known of the alternative regulatory forms. Here prices are allowed to change based on inflation, productivity, and exogenous factors. Here, as opposed to some of the above-mentioned alternative regulatory form, regulatory control has shifted from earnings to prices. The general form of this relationship is:

$$\Delta\%P = \Delta\%GDPPI - X + Z$$

P = price of the regulated service
$GDPPI$ = Gross Domestic Product Price Index
X = productivity
Z = exogenous factors

The change in the GDPPI represents the effect of inflation. A productivity offset, the *X factor*, is defined by the commission to represent the expected productivity in the telecommunications sector over the rest of the economy. The idea is to pass on expected productivity to the consumer. Z represents adjustments due to unexpected factors beyond the firm's control.

There are many variations of this plan if only because every plan has a different X-factor or Z-factor. However, some variant of this plan governs the major ILEC in 20 of the states and the District of Columbia

Pricing Flexibility

Pricing flexibility is usually applied to those services considered competitive. The only requirement is that prices must cover their (incremental) costs.

Deregulation

This is the regime is furthest from RBROR. Deregulation is usually mandated by legislation. Rates and earnings are not regulated. Rate changes and the introduction of new services can take place automatically within days of filing with the commission.

Normative Pricing

This is a regulatory regime that falls outside of the usually definitions of alternative regulation and is not defined anywhere. It represents the experience of this study. This is a more general category that does not rely on specific rules. Here Commissions are obliged by the legislature to set prices usually based on incremental costs (TSLRIC), market considerations and *commission judgement*. Earnings or revenue requirements are explicitly forbidden.

Access - Mirroring

In some State jurisdictions the intrastate access charges are set at levels that mirror the rates established by the FCC.

C. DATA

The goal of this study is to examine those economic forces that will effect the decisions of ILECs to deploy advanced telecommunications services within a wire center serving area. In order to undertake such an analysis, relevant data must be gathered at the wire center serving area level.

The data used contains data from many disparate sources such as government reports, census data, telecommunications market information, and questionnaires.

SUPPLY

On the supply side, information on the characteristics of the ILEC such as measures of firm size and availability of ATS was needed at the wire center level. Measures of firm size such as number of lines or sales is available from reports such as ARMIS. However, the level

of data is not disaggregate enough to be used at the wire center serving area level. Instead, ILEC firms were classified as being large, medium or small.[14]

Availability of the advanced telecommunications services (ATS) was obtained from the NECA[15] 4 Tariff. Information is collected on the availability of services at each ILEC's wire center based on information supplied by each ILEC.

Additional data was obtained on whether an ILEC: (1) was classified as rural or non-rural, (2) was eligible for Rural Utility Services (RUS) [16] subsidies, (3) was regulated under a federal price-cap or rate-of-return for its interstate services, (4) had received approval under the 271 process to offer inter-LATA service, (5) is a subsidiary of a larger company.

DEMAND

Characteristics of the market that would affect demand were obtained from the U.S. Census Bureau. This information was supplied by zip code, which had to be translated into wire center values. This supplied the study with such demographic and economics information as the number of households, the population, the median household income, employment status, statistics on education as well as ethnicity, etc.

Business data was obtained from *Zip Code Business Patterns 1999*.[17] This data set provided information such as total employment, total number of establishments and the number of firms in different sizes based on numbers of employees for nine different SIC codes. The companies were organized into three size categories: small (1- 19 employees), medium (20 - 99 employees), large (μ 100 employees).

COMPETITION

Using the Local Exchange Routing Guide (LERG)[18] database, the horizontal and vertical coordinates of each wire center were obtained for each ILEC and each CLEC's point of presence. This information was used to determine the number of CLECs within 1, 3, 5, 7, and 10 miles from an ILEC's wire center.

REGULATION

[14] ILECs which are part of regional bell operating companies (RBOCs) were one classification. They and GTE were the large firms. Medium size firms were Alltel, Carolina Tel, Century Tel, Cincinnati Bell, Citizens Telecom, Frontier, Sprint, United, TDS Telecom, and Valor. The remaining ILECs were considered small. The only difference with this classification format and the FCC in its *Statistics of Common Carrier* was in classifying CenturyTel, TDS and Valor as mid-sized ILECs.

[15] National Exchange Carrier Association, Inc. (NECA) was founded in 1983 and is responsible for assisting the FCC in administering various tariffs as well as supervising its access services pool. The NECA 4 Tariff contains information on services supplied at each ILEC's wire center as well as its coordinates.

[16] The Rural Utilities Service was founded to encourage deployment of modern infrastructure in rural areas and provides subsidized loans for eligible rural companies.

[17] *ZIP Code Business Patterns 1999* was published November 2002 and is provided on CD. The data is available on an annual basis. The 2000 data set was only released recently.

[18] The Local Exchange Routing Guide (LERG) produced by Telecordia™ Routing Administration contains detailed routing information to support the local exchange network configuration within the North American Numbering Plan (NANP).

To capture the regulatory tone of a state's commission, information was obtained on the UNE loop rate established for each state's RBOC as well as it embedded cost. The ratio of UNE rate to embedded cost is viewed as a proxy for the state's regulatory climate.[19]

A more direct method for addressing the effect of regulation/deregulation was obtained initially by examining Abel and Clements (1998)[20], but primarily by developing a questionnaire that was sent to every state commission and the District of Columbia. This questionnaire[21] asked which forms of regulation did each ILEC face for eight broad categories of services: business basic, business other, business competitive, residence basic, residence other, residence competitive, intrastate switched access, and advanced telecommunications services. The forms of regulation were variants of those stated above. It also asked if the ILEC was obligated under Section 251 (c) of the Telecommunications Act to supply UNEs upon request.[22]

IV. EMPIRICAL METHDOLOGY AND ANALYSIS

A. INTRODUCTION

In many ways, the methodological approach adopted herein has much in common with the work of Greenstein, Masters, and Spiller (1995), Bartolini and Baussola (2001), and Ai and Sappington (2002. Greenstein, Masters, and Spiller (GMS) and Ai and Sappington (AS) both examine the effects of incentive regulation on network modernization in the telecommunications industry. AS also controls for competition. Both competition and regulation are examined in this study. A major difference in the approaches taken by this study and GMS and AS is that this study has not accounted for time. This study will examine the U.S. telecommunications market for the year 2001 in a manner similar to the cross-sectional approach taken Bartolini and Baussola.

Like Bartolini and Baussola, this study uses its data set to describe technological adoption as a discrete choice typical of qualitative-dependent variable models. We will model the probability of deployment of an advanced telecommunications service as of a given year, 2001, as a function of a set of explanatory variables - i.e, the economic determinants of technological innovative adoption. The empirical model can be summarized as follows:

$$y_i = \beta_0 + \sum_{j=1}^{k} \beta_j x_{ij} + \mu_i \qquad (1)$$

[19] Billy Jack Gregg, *Survey of Unbundled Network Element Prices in the United States (updated January 1, 2002)*, Columbus: National Regulatory Research Institute (NRRI).

[20] A supplement to this report was also referenced - *Forms of Regulation for Major LECs in the U.S. States (as of October 2000)*, Columbus: National Regulatory Research Institute (NRRI).

[21] This was a monumental undertaking. It took over nine months to complete. Not all commissions were able to provide answers so readily. Answers to many questionnaires were achieved by reading numerous state documents and orders. See Appendix C for a list of official documents read.

[22] Section 251(c) of the Telecommunications Act obligated carriers to provide UNEs and UNE-P upon request. However, Section 251(f) of the Act allows for exemptions. The state commission decides if a carrier satisfies the conditions for exemption. All RBOCs are obligated. Usually rural companies are exempt. More recently, some state commissions have eliminated that exemption if a carrier moves to incentive regulation.

where:

y_i … is a dummy variable that takes on the value of 1 if the advanced service has been deployed in wire center serving area i and 0 otherwise, i = 1, …, m
α_0 … is a constant
α_j … is the coefficient of the explanatory variable x_j
x_{ij} … is the value of the jth explanatory variable associated with the ith wire center serving area, i = 1, …, m; j = 1, …, k
ε_i … is the error term associated with the observation of y_i
m … the number of wire centers is the study
k … the number of explanatory variables.

We assume that $E(\boldsymbol{\mu}|\mathbf{x}) = \mathbf{0}$.

B. EXPLANATORY VARIABLES

In defining the set of explanatory variables that will be incorporated in the model, one must recall the discussion on the Schumpeterian hypotheses and the various studies that examined some aspect of those hypotheses on some measure of technological innovation. One must also remember the admonishment of some like Cohen and Levin (1989) to look beyond just firm size and or market power to a broader consideration of the economic determinants of technological innovation. With that view in mind, this study will include characteristics of the ILEC in addition to firm size, elements of the market structure - particularly demand, the competitive presence, the size of the market, the characteristics of the customers - and regulation. The study even touches on technological opportunity.

ILEC Firm Size

The ILECs are divided into one of three categories –small (*LECSMLL),* mid-size (*LECMID),* or large (*LECLRG*) - based on the financial strength of its holding company. The large companies are of affiliates of RBOCs. Each affiliate is the dominant local telecommunications provider in each state where it provides service. The associated holding companies - i.e., the RBOCs - consist of some of the largest companies in the U.S. Each is a Fortune 500 company.

The mid-size ILECs are also subsidiaries of large companies - but not as large as the holding companies of those classified here as large. These mid-size companies are subsidiaries of Alltel, Broadwing (Cincinnati Bell) CenturyTel, Citizens/Frontier, Sprint/United, and Valor. With the exception of Sprint, these holding companies tend to be part of the Fortune 1000. Sprint is a Fortune 500 company with revenues that exceed those of Qwest as well as BellSouth. It tends to be the ILEC in second and third tier markets - except for its provision of service in Las Vegas. Valor is the smallest of these mid-size firms. It is a privately held company with little available public financial information. All other ILECs are classified as small. For the most part, the smaller companies tend to be locally-owned operations. Some are cooperatives. None are in the Fortune 1000. Note that this classification comports with the FCC's *Statistics of Common Carriers.* The only difference is this study includes CenturyTel, TDS, and Valor in the mid-size classification.

Based on the Schumpeterian hypothesis, one would expect the firms associated with larger holding companies to have the greater financial resources to undertake the deployment of advanced services. Financial strength also means the company has the marketing and technical resources to support such undertakings. The literature has also shown that larger companies have easier access to financial support from banks and other institutional lenders. However, the literature also indicated that the general consensus in the economic community is that size does not matter. The more recent articles that indicate size does matter have developed more complex formulation than in this study to capture the effect of size.

The variables are:

Other ILEC Characteristics

The FCC classifies an ILEC as being a rural or non-rural carrier.[23] One would expect that a rural classification would have a negative impact on the deployment of advantage services. Rural carriers are not located in high-density urban areas that are attractive to the deployment of advanced services due to economies of scale. The associate dummy variable is *RURAL*.

In order to encourage rural companies to invest in modern network infrastructure, the Rural Utilities Services was established under the U.S. Department of Agriculture. Eligible companies can obtain low cost loans to invest in the new technologies. Thus, one would expect those companies who are eligible for these subsidies to be more apt to deploy advanced services in its markets - ceteris paribus. This dummy variable is *RUS*. Note that being eligible does not necessarily mean an ILEC has actually borrowed nor does it mean that such companies are only rural providers..

Regulation

The primary forms of local regulation examined will be those related to the provisioning of advanced telecommunications services by the ILEC. A review of the data from the completed questionnaires on the regulatory history in each state and the District of Columbia revealed that only a subset of the primary forms of regulation were applicable to the provisioning advanced telecommunications services. The major forms of local regulation for advanced services were rate-of-return, pricing flexibility, and deregulation. Other forms were indexed price caps, non-indexed price caps, and price caps/rate freeze occasionally accompanied by service or infrastructure obligations. These are dummy variables where a value of one indicates that that this is the form of regulation faced a particular ILEC in a particular wire center serving area for the provisioning of the advanced service. The variables from most to least regulated:

RBROR - Rate base rate-of-return
CAP - Either a rate freeze or a straight price cap
NONINDX CAP - A non-index price cap
INDXCAP - Indexed price cap
NORMATIV - Normative pricing
CHOICE - The ILEC is given the "choice" of the available forms of alternative regulation.

[23] The definition of rural carrier is provided in Section 3(a)(2)(47) of the *Telecommunications Act*. Although there are several criteria, it is essentially any carrier that does not provide service in an "urbanized" area.

PFLEX - Flexible pricing for competitive services
DEREG - Deregulated

An ILEC's regulation of interstate services is determined by whether it is under either rate-of-return regulation or federal (indexed) price caps. This is designated by a dummy variable *FEDCAP*, which equals 1 if the ILEC is under a federal price cap and 0 if it is under rate-of-return regulation.

Other regulatory variables include whether an ILEC has received 271 Approval and whether the ILEC is obligated under Section 251 of the Telecommunications Act to provide unbundled network elements to competitive providers upon request. The dummy variable *APPRV271* is positive if the RBOC affiliate has received approval by the FCC to provide in-region interLATA service. A positive value means the ILEC's markets are viewed as being open to competition. Increased competition or the threat of competition should provide an incentive to deploy more advanced services.

UNE obligation is captured with the dummy variable *UNEOBLIG*. If there is no UNE obligation, the market is not open to competition. According to several respondents involved with the survey on regulation, one of the conditions for receiving an alternative form of regulation is an agreement by the ILEC to allow competition in its franchised territory.

Market

A number of demographic variables are included to capture a sense of the market:

HSEHLDS - The number of households
EMPLYEES - The number of workers employed by business establishments
DENSITY - The number of people per square mile
AVGHHINC - Average household income

Most studies find that new products are deployed more readily in large, densely populated areas - i.e., urban areas. The average household income can be taken as a proxy for the socio-economic status of the wire center serving area.

The ratio of the loop UNE rate to its embedded cost, *PRATIO* (price ratio), is an indicator of the state's regulatory climate. A higher ratio suggests a regulatory climate more supportive of the state's ILECs and less supportive of non-facility based competition. It is difficult to predict how this variable will affect deployment. A higher value will enable ILECs to reap a higher return on their investments. However, a lower value will encourage competition. The underlying thesis for policymakers as well as economists is that competition forces firms to innovate.

Since *PRATIO* is state-specific, it is also an indirect measure of an aspect of technological opportunity within a state.

One of the key variables in this study is the level of competition faced by the ILEC. To that end, the variable *NCOMPS* measures the number of competitors operating within three miles of the ILEC's wire center. The actual measure was the natural log of *NCOMPS* +1 to capture the non-linearity of the effect of competition on adoption. This could have been extended to ten miles, but the decision was to provide a more conservative effect. Ideally, one would have liked a measure of the effectiveness of the competition - the market share of these

competitors as compared to the ILEC. Still, this study does provide a viable measure of competitive threat by the number of competitors within a reasonable distance.

Buyers

The services examined in this study are primarily used by business establishments although some residential user such as work-at-home could take advantage of DS lines and packet switching. However, for the most part, it would seem that larger firms would be more likely to purchase these advanced services. Thus, there is a variable for large firms, *LRGFIRMS* who are located in the service territory of the ILECs wire center. In addition, studies focusing on the telecommunications market invariably include a variable for the number of firms in industries that are traditionally high users of telecommunications services - finance and insurance (SIC 52), real estate (53). Some also include professional, scientific and technical services (54).. In addition to these more traditional industries, this study also adds the information industry (51), education (61) and health care (62). The intention is to capture the effects of major users such as telecommunications resellers, radio and television networks in the information industry, large universities in the education industry, and hospitals in the health industry. Consideration was given to focusing only on the large users in these industries, but there was no large user data for education or health care. In addition, there was concern of possible collinearity between such a variable and the previously defined variable for large users. See Table 4.1 for a summary list of the set of explanatory variables.

C. RESULTS

The results from the estimations are provided in Tables 4.2, which is summary of the results obtained from the analysis of each ATS. Underlying the analysis of each service are probit regressions where competition is treated as endogenous to the model. The detailed results are necessary because many of the quantity or non-dummy variables such as households (*HSEHLDS*) or number of business establishments (*NFIRMS*) appear as .000 because the summaries only provide results to three decimal places. In addition, the results for these variables are related to the impact of a single person or a single firm.

What is interesting about all of the estimates across all services is that the vast majority of the variables are significant at the 1% level. The variables whose significance varied most were the industry variables for the expected high telecommunications users. They were not always significant and in one instance, optical carrier, came close to being jointly insignificant.

Another valuable point was that alternative estimation approaches for each service produced similar results. This was consistent across all studied services. The coefficients might differ across estimation approaches - as would be expected - but the level of significance was the same.

The surprises were that the measure of competition was always a significant variable in the deployment of advanced services and that some alternative forms of regulation produced negative impacts on innovation relative to rate base rate-of-return regulation.

The choice of instrument for the natural log of the number of competitors was the natural log of the number of employees. There were many choices for instruments in probit (IV) large firms from the finance, insurance, real estate, technical services, and information industries.. This is an area that needs further exploration. The particular insight gained from

this simple analysis of competition is how closely competitors seem to be associated with areas where the traditional high users of telecommunications are located. In other words, the competitors know their markets and their customers.

Because of the large number of variables included in the regressions, there likewise a large number of interpretations of the results. We will concentrate on just the more noteworthy impacts.

PACKET SWITCHING

Aside from the regulatory results, the packet switching results are essentially what one would have expected. This was especially true of large ILECs (*LECLRG*). Having a large ILEC as a provider of local services increased the probability of deployment by .218. What was surprising, however, is that among the highly significant variables, large business establishments (*LRGFIRMS*) and density had negative impacts. This suggests that not all large firms are candidates for packet switching type services. This is confirmed by a preliminary estimation using an LPM approach that indicated that large firms in the financial and information industries had a significant positive impact. These variables were not included in the results presented here.

The negative value due to density may not be so surprising. Density is population per square mile. In other words, it is a measure of residential density as opposed to business density. So the negative value could be seen as consistent with the expectation that packet switching is for medium to large commercial interests that would not be located in densely populated residential areas.

The results from the regulatory variables are probably the most interesting. All are highly significant, but deregulation, indexed price-caps, and pricing flexibility have negative impacts relative to rate base rate-of-return (RBROR) regulation in the deployment of packet switching. This is significant because it begins to suggest that the importance attached to incentive or alternative regulation as a catalyst for innovation may be overstated - especially when one controls for other variables such as competition.

Also, the coefficient on UNEOBLIG suggests that ILECs are less likely to innovate in markets which are not subject to the threat of competition.

DIGITAL SIGNAL 1 (DS1)

The estimates suggest that the DS1 market is not for the large providers or the large commercial users. It also suggests that competition is a factor. These are not inconsistent results. It is possible that the large carrier and the larger firms have moved on to more cutting edge technologies. But the significantly positive impact from competition suggests that competitors may be more efficient I supplying this older technology. DS1 is the one service that would have some residential applicability. Average household income and number of households have significantly positive impacts. An increase of 1,000 households will increase the probability of deployment by almost 1% (.007).

Again, the regulatory variables are significant and indexed price caps and pricing flexibility have negative impacts. As opposed to packet switching, deregulation has a highly significant positive effect.

It is important to note that governance by deregulation can be somewhat misleading at times. Not all ILECs governed by deregulation can be viewed as being in a competitive environment. Deregulation is a legislative act and is often the form of regulation for cooperatives, tribal phone companies, and many very small companies who are on intimate terms with there customers. DS1 is a service that these smaller-type companies could provide. Besides it is a relative small effect. The presence of deregulation increases the probability of deployment by .047 relative to RBROR.

DIGITAL SIGNAL 3 (DS3)

This service seems to have more unexpected results. For one, the smaller and mid-sized companies seem more likely to deploy DS3 than the larger ILECs.[24] Competition is also insignificant. Is it possible that DS3 like DS1 services are not being actively marketed by the mid to large firms because there are focusing on more advanced services such as (Gigabit) Ethernet? Large firms have a significantly negative impact. Households are insignificant.

Once again, we are seeing the same negative impacts to deployment of advanced services from deregulation, indexed price caps, pricing flexibility, and straight price-caps.

OPTICAL CARRIER (OC)

At first glance, the results for optical carrier seem somewhat at odds with what one would have expected. Large providers although positive are statistically insignificant. Mid-sized ILECs have less impact than smaller ILECs.[25] However, competition has a highly significant impact.

The following variables were highly significant positively: average household income, UNE rate to embedded cost ratio, real estate industry. However, other variables that one would have expected to have an impact - information industry, technical services, large firms - actually had a significantly negative impact.

OVERALL SUMMARY ACROSS ALL SERVICES

Some factors were consistent in their impacts. Rural and RUS eligibility had the desired impacts. Another supplier characteristic, UNE obligation, was always positive and highly significant (except in OC). This is interesting since all RBOC affiliates have UNE obligations.

On the demand side, average household income and the real estate industry were always significantly positive. Other demand variables were usually significant but surprisingly not always positive - number of households, large business enterprises. This needs to be explored further.

PRATIO had very strong positive effects on the deployment of some of the services (packet switching and DS1), but negative on DS3. This suggests that high UNE rates do influence the ILEC's deployment of some advanced services. However, it is insignificant in

[24] This will be discussed further in the summary to this section

[25] The impact of smaller ILECS in the provision of optical carrier - a version of fiber optics - may not be so surprising. A report by Legg Mason, *Reshaping Rural Telephone Markets*, reveals that larger companies are disposing of their rural territories to smaller, more efficient operators who better understand how to operate in rural markets.

the deployment of OC services. This is also consistent with the regulatory effects. There is a greater probability of deployment where the ILEC has some protection from the vagaries of the market. Note the highly significant positive effects from non-indexed price-caps (the ILEC gets a guaranteed increase in rates each year) and normative pricing versus deregulation, indexed price-caps, and pricing flexibility. Once other factors are controlled for, these forms of regulation do not have the desired impact. This and the significantly positive impact of competition might be the most revealing and surprising insights from this study.

V. CONCLUSIONS AND POLICY IMPLICATIONS

The results of this study suggest three things: (1) Schumpeter and Schmookler were right; (2) analysis and policy needs to be designed to fit the characteristics of the market; (3) the implementation of alternative regulation needs to be re-thought both by economists and policymakers.

One of the Schumpeter hypotheses suggested that large firms with monopoly power were better positioned to provide the new technological innovations. The study tends to support this thesis in those markets where one would expect the larger ILECs to be active. This was particularly true in the deployment of packet switching. The fact that larger providers did not reveal themselves in the DS1 and DS3 markets may not be so surprising. These services have been around since the 1960s. It would be interesting to see what newer services these companies might be marketing such as (Gigabit) Ethernet. Dodd (2002) highlights the many advantages of Ethernet over the other advanced telecommunications services including ease of installation and lower cost.

Another aspect of Schumpeterian thought that seemed to reveal itself is his argument that it is not price competition that is most important but:

> …the competition from the new commodity, the new technology, the new source of supply, the new type of organization (the largest-scale unit of control for instance) - competition which commands a decisive cost or quality advantage and which strikes not at the margins of the profits and the outputs of the existing firms but at their foundations and their very lives.[26]

The study seems to suggest that those companies the have UNE obligations, but are not RBOC affiliates, may have captured this approach to competition. These are not necessarily large companies, but they have embraced competition and are doing so by investing in newer technologies. These are companies that seem to be transforming some of the rural ILECs into more efficient operations.

In many ways, Schmookler is vindicated by this study. Once one accounts for the characteristics of the particular market for a service, it is the demand factors that are highly significant. Note the responses of the demand factors in this study - average household income, number of households, number of business establishments, number of large firms, and the responses of the various individual industries depending on the particular market being studied. Demand has a consistently significant impact on deployment of advanced services and by implication on technological innovation.

[26] This passage from Schumpeter (1942, 84) is presented in its entirety at the end of Section VI.

Another important result is that markets matter. The approach to the study of one market may not be valid in the study of second. The market for each of these advanced services is different. The data set used in the analyses was the same, but the results differed. The implication is that policy must be fashioned to fit individual markets if it is to be successful.

The study's most surprising result is that incentive regulation does not lead to the deployment of advanced services. This promises to be controversial because it seems to go against a widely held belief about the advantages of alternative regulation - i.e., that it will lead to newer services. Once other factors are controlled for, these incentive regulation plans have a negative impact on the deployment of the advanced services examined in this study. What this study does suggest for policymakers is that not only must they reduce the barriers to competition, but that they will have to receive a firm commitment from the ILEC to provide advanced services in exchange for alternative regulation.

APPENDIX - TABLES

Table 4.1 - EXPLANATORY VARIABLES

Name	Type	Dummy	Comments
APPRV271	Supplier	y	RBOC affiliate has satisfied the 14 points indicative of sufficient competition in its region to warrant permission to provide in-region interLATA service.
FEDCAP	Supplier	y	At the interstate level, the ILEC is regulated by an indexed price cap
LECLRG	Supplier	y	These are the RBOC affiliates.
LECMID	Supplier	y	Mid-size ILECS. Affiliates of Alltel, Broadwing, CenturyTel, Citizens/Frontier, Sprint/United, Valor
LECSMLL	Supplier	y	All other ILECs
RURAL	Supplier	y	Indicates the ILEC is considered a rural carrier.
RUS	Supplier	y	Indicates the ILEC is eligible to receive loan subsidies from the Rural Utilities Service
UNEOBLIG	Supplier	y	ILEC is obligated under Section 251(c) of the Act to provide UNEs upon request.
AVGHHINC	Market		Average household income in the wire center serving area
DENSITY	Market		Number of people per square mile
EMPLYEES	Market		The number of employed by the firms in the wire center serving area
HSEHLDS	Market		The number of house holds in the wire center serving area
NCOMPS	Market		The number of competitors whose point-of-presence is within 3 miles of the ILEC wire center.
PRATIO	Market		This is the ratio of the loop UNE rate to its embedded cost
EDUC	Buyer		The number of firms in the education industry (61)
FINC	Buyer		The number of firms in the finance and insurance industries (52)
HEALTH	Buyer		The number of firms in the health care industry (62)
INFO	Buyer		The number of firms in the information industry (51)
LRGFIRMS	Buyer		The number of large firms in the wire center serving area.
LRGINFO	Buyer		The number of large firms in the information industry - SIC 51
NFIRMS	Buyer		The number of business establishments
REALEST	Buyer		The number of firms in the real estate industry (53)
TECHSRV	Buyer		The number of firms in the professional, scientific, and technical services industries (54)
CAP	Regulation	y	Either a rate freeze or a straight price cap
CHOICE	Regulation	y	ILEC has a set of available alternative forms of regulation to choose from.
DEREG	Regulation	y	The ILEC or a set of services has been deregulated by the legislature. Primarily cooperatives and Indian tribal firms.
INDXCAP	Regulation	y	Traditional indexed price cap.
NONINDXCAP	Regulation	y	Non-indexed price cap. Rates are allowed to rise annually based on a specified percentage
NORMATIV	Regulation	y	Commission sets rates based on economic costs, market conditions and consumer welfare, but precluded by legislation from any rate base or earnings projections.
PFLEX	Regulation	y	The ILEC is given pricing flexibility for competitive services. The only obligation is that prices must exceed economic costs.
RBROR	Regulation	y	Traditional rate base rate-of-return regulation
*NONINDXCAP*NTWKOBLIG*	Regulation	y	Interactive dummy to capture non-indexed price-cap with service obligations
*PFLEX*NTWKOBLIG*	Regulation	y	Interactive dummy to capture pricing flexibility along with service

			obligations

Table 4.2 - Summary of Probit (IV, dF/dx) for all Services

	PCKTSW	DS1	DS3	OC
+ LNCOMPS	0.696	0.605	0.912	0.181
	(4.73)**	(3.79)**	(6.51)**	(5.77)**
APPRV271	-0.016	-0.260	-0.024	-0.010
	(1.02)	(15.94)**	(1.64)	(4.61)**
FEDCAP	-0.374	-0.194	-0.110	-0.139
	(13.88)**	(8.26)**	(4.43)**	(3.48)**
LECLRG	0.218	-0.132	-0.359	0.020
	(6.36)**	(3.44)**	(9.25)**	(1.39)
LECMID	0.123	0.113	0.005	-0.033
	(5.80)**	(5.70)**	(0.28)	(3.65)**
RURAL	-0.125	-0.427	-0.209	-0.025
	(4.07)**	(13.20)**	(8.16)**	(2.96)**
RUS	0.060	0.050	0.044	0.004
	(3.34)**	(2.84)**	(2.53)*	(1.08)
UNEOBLIG	0.136	0.117	0.058	-0.004
	(7.28)**	(6.17)**	(3.39)**	(0.80)
+ AVGHHINC	0.000	0.000	0.000	0.000
	(8.67)**	(4.72)**	(10.91)**	(10.20)**
DENSITY	-0.000	-0.000	-0.000	-0.000
	(4.77)**	(4.99)**	(6.06)**	(5.66)**
HSEHLDS	-0.000	0.000	-0.000	-0.000
	(1.49)	(3.35)**	(1.63)	(2.30)*
PRATIO	0.537	0.217	-0.065	0.005
	(16.28)**	(6.35)**	(2.14)*	(0.74)
NFIRMS	0.000	0.000	0.000	0.000
	(6.81)**	(1.75)	(3.05)**	(3.19)**
LRGFIRMS	-0.010	-0.006	-0.008	-0.002
	(5.52)**	(3.01)**	(4.59)**	(4.68)**
EDUC	0.000	-0.011	0.002	0.000
	(0.11)	(4.31)**	(1.45)	(0.82)
FINCE	-0.001	-0.000	-0.001	-0.000
	(3.51)**	(0.00)	(3.81)**	(3.81)**
HEALTH	-0.001	-0.000	-0.001	-0.000
	(2.80)**	(0.96)	(4.06)**	(3.13)**
INFO	0.003	0.003	-0.000	-0.000
	(2.60)**	(1.60)	(0.85)	(1.91)
+ REALEST	0.006	0.010	0.005	0.001
	(6.26)**	(8.23)**	(5.26)**	(4.81)**
TCHSRV	-0.002	-0.002	-0.002	-0.000
	(8.48)**	(5.58)**	(6.18)**	(5.67)**
CAP	0.584	-0.089	-0.104	
	(9.07)**	(1.71)	(2.93)**	
DEREG	-0.196	0.038	-0.008	0.024
	(12.40)**	(2.15)*	(0.51)	(5.21)**
INDXCAP	-0.126	-0.150	-0.088	-0.010
	(5.41)**	(5.41)**	(4.48)**	(2.70)**
NONINDXCAP	0.122	0.463	0.030	-0.001
	(3.51)**	(11.92)**	(0.98)	(0.20)
+ NORMATIV	0.302	0.362	0.273	0.396
	(4.61)**	(6.87)**	(3.63)**	(3.37)**
PFLEX	-0.143	-0.037	-0.011	-0.004
	(8.71)**	(2.09)*	(0.71)	(1.18)
NONCAPNTWK	-0.243	-0.532	-0.129	

	(8.86)**	(15.11)**	(5.51)**	
PFLEXNTWK	0.012	-0.043	-0.131	-0.011
	(0.40)	(1.26)	(6.98)**	(3.08)**
Observations	14528	14528	14528	14119

Absolute value of z statistics in parentheses
* significant at 5%; ** significant at 1%
+ positve and statistically significant impact across all services

Note that values of less than .0005 are listed here as .000. This is usually associated with variables where the marginal impact of say another dollar in average household income (AVGHHINC) or another household (HSEHLDS) would not be expected to be large.

REFERENCES

ABEL, JASON. 2000. *The performance of the state telecommunications industry under price-cap regulation: An assessment of the empirical evidence.* NRRI 00-14 (September). Columbus, OH: The National Regulatory Research Institute.

ABEL, JASON R., AND MICHAEL E. CLEMENTS. 1998. *A time-series and cross-sectional classification of state regulatory policy adopted for local exchange carriers.* NRRI 98025. Columbus, OH: The National Regulatory Research Institute.

ACS, ZOLTAN, AND DAVID AUDRETSCH.1987. Innovation, market structure, and firm size. *The Review of Economics & Statistics* 69(4): 567-574.

AGHION, PHILIPPE, CHRISTOPHER HARRIS, PETER HOWITT, AND JOHN VICKERS. 2001. Competition, imitation and growth with step-by-step innovation. *Review of Economic Studies* 68: 467-492.

AHN, SANHOON. 2002. Competition, innovation and productivity growth: A review of theory and evidence. *OECD Economics Department Working Papers No. 317.*

AI, CHUNRUNG, AND DAVID SAPPINGTON. 2002. The impact of state incentive regulation on the U.S. telecommunications industry. *Journal of Regulatory Economics* 22(2): 133-160.

ARVANITIS, SPYROS. 1997. The impact of firm size on innovative activity - an empirical analysis based on Swiss firm data. *Small Business Economics* 9: 473-490.

BALDWIN, WILLIAM, AND JAMES T. SCOTT. 1987. *Market structure and technological change*. Chichester: Harwood Academic Publishers.

BALHOFF, MICHAEL, TIMM BECHTER, MARK HALL, AND CHRISTOPHER KING. 2001. *Reshaping Rural Telephone Markets,* Baltimore, Maryland, Leggs Mason Research.

BARTOLONI, ELEONORA, AND MAURIZIO BAUSSOLA. 2001. The determinants of technology adoption in Italian manufacturing industries. *Review of Industrial Organization* 19(3) (November): 305-328.

BAUER, JOHANNES. 1997. Market power, innovation, and efficiency in telecommunications: Schumpeter reconsidered. *Journal of Economic Issues* 31(2) (June): 557-565.

BLUNDELL, RICHARD, RACHEL GRIFFITH, AND JOHN VAN REENEN. 1999. Market share, market value and innovation in a panel of British manufacturing firms. *The Review of Economic Studies* 66(228) (July): 529-554.

BOONE, JAN AND THEON VAN DIJK. 1998. Competition and innovation. *De Economist* 146(3) (October): 445-461.

BOURREAU, MARC AND PINAR DOGAN. 2001. Regulation and innovation in the telecommunications industry. *Telecommunications Policy* 25: 167-184.

BUDDE, PAUL. 2003. Data technology: Introduction and frame relay. Database online. http://www22.verizon.com/about/community/learningcenter/articles/displayarticle1/0,4065, 1134z1,00.html. Accessed 2 April.

COHEN, WESLEY. 1995. Empirical studies of innovative activity. In *Handbook of the Economics of Innovation and Technological Change.* Edited by P. Stoneman. Cambridge: Blackwell Publishers.

COHEN, WESLEY M., AND STEVEN KLEPPER. 1996. A reprise of size and R&D. *Economic Journal* 106 (July): 925-951.

COHEN, WESLEY, AND RICHARD LEVIN. 1989. Empirical studies of innovation and market structure. In *Handbook of Industrial Organization.* Edited by R. Schmalensee and R. Willig. Amsterdam: North Holland. Volume II: 1059-1107.

CRANDALL, R.W. 1999. Managed competition in U.S. telecommunications. AEI-Brookings Joint Center for Regulatory Studies. Working Paper 99-1.

CRÉPON, BRUNO, EMMANUEL DUGUET, AND JACQUES MAIRESSE. 1998. Research, innovation and productivity: An econometric analysis at the firm level. *Economic of Innovation and New Technology* 7: 115-158.

DODD, ANNABEL. 2002. *The essential guide to telecommunications*., 3rd ed Upper Saddle-River, NJ: Prentice-Hall.

DOSI, GIOVANNI. 1988. Sources, procedures, and the microeconomic effects of innovation. *Journal of Economic Literature* 26(3) (September): 1120-1171.

Economist. 1999a. Survey: Innovation in industry, 20 February.

Economist. 1999b. Millennium Special Edition, 31 December.

FARBER, STEPHEN. 1981. Buyer, market structure and R&D effort: A simultaneous-equations model. *Review of Economics and Statistics* 63(3) (August): 336-345.

FCC. 2003. FCC adopts new rules for network unbundling obligations of incumbent local phone carriers. *FCC News*, 20 February.

FLOYD, EUGENE. 2003. An econometric analysis of the factors affecting the deployment of advanced telecommunications services. Ph.D. dissertation, City University of New York Graduate Center.

FREEMAN, CHRIS, AND LUC SOETE. 1997. *The Economics of Industrial Innovation.* 3rd ed. Cambridge: MIT Press.

GREENSTEIN, SHANE, SUSAN MCMASTER, AND PABLO SPILLER. 1995. The effect of incentive regulation on infrastructure modernization: Local exchange companies' deployment of digital technology. *Journal of Economics & Management Strategy* 4(2): 187-236.

GROSSMAN, GENE, AND ELHANAN HELPMAN.1994. Endogenous innovation in the theory of growth. *Journal of Economic Perspectives* 8(1) (Winter): 23-44.

HALL, BRONWYN AND BENITA KAHN. 2003. Adoption of new technology. In Derek C. Jones' *Handbook of Economics in the Electronic Age,* Academic Press

HORAK, RAY. 2002. *Communications systems and networks.* 3rd ed. Indianapolis: Wiley Publishing.

JAFFE, ADAM. 1988. Demand and supply influences in R&D intensity and productivity growth. *The Review of Economics and Statistics* 70(3): 431-437.

KAMIEN, MORTON, AND NANCY SCHWARTZ. 1975. Market structure and innovative activity: A survey. *Journal of Economic Literature* 13: 1-37.

KAMIEN, MORTON, AND NANCY SCHWARTZ. 1982. *Market structure and innovation.* Cambridge: Cambridge University Press.

LAFFONT, JEAN-JACQUES, AND JEAN TIROLE. 2000. *Competition in telecommunications.* Cambridge: MIT Press.

LOURY, G.C. 1979. Market structure and innovation. *Quarterly Journal of Economics* 93: 395-410.

MOKYR, JOEL. 1992. *The lever of riches.* Oxford University Press.

NEWTON, HARRY. 1998. *Newton's telecom dictionary.* 14th ed. New York: Flatiron Publishing.

New York Times, various issues.

PRIEGER, JAMES. 2001. Telecommunications regulation and new services: A case study at the state level. *Journal of Regulatory Economics* 20(3): 285-305.

SAPPINGTON, DAVID, AND DENNIS WEISMAN.1996. *Designing incentive regulation for the telecommunications industry.* Washington, D.C.: AEI Press.

SAPPINGTON, DAVID. 2002. Price regulation and incentives. In *Handbook of telecommunications economics.* Edited by Martin Cave, Sumit Majumdar and Ingo Vogelsang. September. New York: North-Holland.

SCHERER, F.M. 1965a. Firm size, market structure, opportunity, and the output of patented inventions. *American Economic Review* 55(5) (December): 1097-1125.

SCHERER, F.M. 1965b. Size of firm, oligopoly, and research: A comment. *Canadian Journal of Economics and Political Science* 31: 256-266.

SCHERER, F.M. 1967. Market structure and the employment of scientists and engineers. *American Economic Review* 57 (June): 524-531.

SCHERER, F.M. 1992. Schumpeter and plausible capitalism. *Journal of Economic Literature* 30(3) (September): 1416-1433.

SCHMOOKLER, JACOB. 1962. Economic sources of inventive activity. *Journal of Economic History*, 22(1) (March): 1-20.

SCHMOOKLER, JACOB. 1966. *Invention and economic growth.* Cambridge: Harvard University Press

SCHUMPETER, JOSEPH. 1942. *Capitalism, socialism and democracy.* 1976 edition. New York: Harper Torchbooks.

SHAMPINE, ALLAN. 2001. Determinants of the diffusion of U.S. digital telecommunications. *Journal of Evolutionary Economics* 11: 249-261.

STONEMAN, PAUL. 2002. *The economics of technological diffusion.* Oxford: Blackwell Publishers.

SUTTON, JOHN. 1998. *Technology and market structure: Theory and history.* Cambridge, Mass. And London: MIT Press.

SYMEONIDIS, GEORGE. 1996. Innovation firm size and market structure: Schumpeterian hypotheses and some new themes. *OECD Economic Studies* No. 27 /II.

TAYLOR, WILLIAM, CHARLES ZARKADAS, AND J. DOUGLAS ZONA. 1992. Incentive regulation and the diffusion of new technology in telecommunications. Paper presented at the Ninth International Conference of the International Telecommunications Society, 11-17 June.

THIRTLE, COLIN, AND VERNON RUTTAN. 1987. *The role of demand and supply in the generation and diffusion of technical change.* Chichester: Harwood Academic Publishers.

VAN CAYSEELE, P.J.G. 1998. Market structure and innovation. *De Economist* 146(3) (October): 391-417.

VOGELSANG, INGO, AND BRIDGER MITCHELL. 1997. *Telecommunications competition: The last ten miles*. Cambridge: MIT Press.

ZOLNIEREK, J., J. EISNER, AND E. BURTON. 2000. *An empirical examination of entry patterns in local telephone markets. Federal Communications Commission.*