CONFIGURATIONS OF THE U.S. INFORMATIN ECONOMY: AN ECONOMETRIC ANALYSIS OF A TELECOMMUNICATIONS INNOVATION DIFFUSION PROCESS

by

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Abstract

Technological change within the telecommunications sector is an integral part of the transition to a more information-intensive economy, in which control over information flows is an increasingly significant aspect of competitive struggles.

The objective of the dissertation is to provide a comprehensive analysis of the adoption of a telecommunications innovation known as "Equal Access." This innovation concerns the varying time taken by local telecommunications companies to implement across their service territories the technical and administrative capability of offering customers direct connectivity to the long distance network chosen from among the competing carriers. It is argued that this innovation is one of the more noteworthy instances of recent technological change in the telecommunications sector because it set in motion a broad range of changes across the gamut of economic and regulatory relationships constituting this sector.

This innovation process is placed in its historical context by tracing the evolution of the regulatory and institutional framework of the U.S. telecommunications sector from the natural monopoly paradigm of the New Deal era to the regulated competition structure emerging along with Equal Access implementation. The technological backdrop of succession from electromechanical through to electronic switching systems is also presented as another necessary element for contextualizing the innovation process under study.

Drawing upon theories of innovation diffusion and regional development and restructuring, an econometric model is developed for explaining the spatial and temporal pattern of this transition process. A highly disaggregate dataset of dates to "cutover" to Equal Access is employed. This schedule of dates, which forms the basis for the dependent variable of the model, is combined with explanatory variables measured at various spatial scales (sub-county, county, metropolitan area, or service territory levels), permitting evaluation of a rich set of hypotheses concerning: the constraints imposed by the spatial configuration of the existing telecommunications infrastructure; the relative importance of economies of agglomeration and scope; and the linkage between the various measures developed in the thesis as indicators of "information intensity" and the rate of innovation. The econometric strategy of running a large number of alternative specifications, using alternative estimation methods (OLS and weighted least squares) and employing datasets at various levels of aggregation, are aimed at demonstrating the robustness of the basic model structure.

The most important variables explaining the pace of Equal Access implementation are shown to be those capturing the variation within regional holding company service territories and within the same type of metropolitan area. Variables designed to capture the degree of centrality of a metropolitan area in the information economy, although accounting for a much smaller porportion of the total variation, clearly demonstrate the existence of a core and a periphery for this telecommunications process.

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Chapter 1

Introduction

1.1 Scope and Main Arguments

The realm of the commodity form of information is becoming vastly extended. Error free and up-to-the-minute information has become a highly valued commodity. Control over information flows, whereby access to information is becoming restricted through the assigning of proprietary rights is an increasingly significant component of competitive struggles. Technological change within the telecommunications sector is an integral part of this process. This transformation can be viewed as an outgrowth of the diffusion of enhanced technologies for capturing, storing, processing, and retriving information, combined with innovations in telecommunications service offerings, in turn, made feasible by upgraded switching and transmission infrastructures. Technological determination, however, offers a very limited explanation. More complete analysis requires focusing on transformations of regulatory structures, organizational designs, managerial strategies, and industrial configurations.

Economists and other social theorists representative of diverse schools of thought are increasingly referring to the current phase of capitalist development as the"information economy." There is, however, an ongoing heated debate concerning whether recent innovations in communications and information processing have created the material basis for fundamental structural transformations of production systems and societal organization (Bell 1989; Castells 1990), or whether these innovations are merely a smooth continuation of much earlier developments (Beniger 1986). Most attempts to quantitatively assess the significance of the transition to a more information-based economy have entailed the measurement of that portion of the labor force defined to be information workers[1]. Baumol, Blackman, and Wolff (1989) have recently argued that evaluation of the structural significance of this transformation is aided by a decomposition of changes in the proportion of the labor force comprised by information workers into an input substition effect, a relative productivity effect, and an output composition effect[2].

I suggest examining the transition to an information economy from another vantage point, namely, from investigation of those social processes that are transforming the structural characteristics of telecommunications networks, the basic infrastructure of the information economy. I will focus on the geographically uneven development of the information economy. Castells has argued that the"information

[1]Relying on a framework initiated by Porat (1977), the OECD (1988) uses a four-way classification of information occupations: information producers;information processors; information distributors; and information infrastructure occupations.

[2]Their work will be discussed below. Part of their work is drawn upon in constructing a key variable utilized in my modeling effort.

mode of production" results in an economic geography characterized by heightened inter-regional cleavage, intra-metropolitan dualism between inner cities and suburbs, and polarization within central cities (Castells 1985). Similarly, Gillespie and Williams have noted that the altered investment criteria associated with new regulatory regimes are tending to transform the character of uneven integration into the information economy– from spatial *asymmetries* into *discontinuties* (Gillespie and Williams 1988). By this they mean that new investments in peripheral areas, rather than being slow in coming, might not come at all.

The main subject matter of the dissertation concerns spatial and temporal patterns of adoption of telecommunications innovations. More specifically, chapter 5 presents an econometric model of the conversion to"Equal Access," a nation-wide process initiated shortly after the divestiture of the Bell Operating Companies from AT&T in 1984, and nearly completed by the end of the decade. Equal Access refers to the technical capability of local telecommunications companies to implement direct connectivity to the networks of the long distance carriers selected by their customers. Equal Access, as an innovation process entails: a technical component–installation of the requisite software to supplement the existing stored program control software of digital telecommunications switching equipment; and an administrative component–surveying and then implementing their customers' choice of inter-exchange carrier, e.g., AT&T, MCI, Sprint, etc. This seemingly minor historical event, I will argue, has important and lasting consequences, warranting the attention of any economist interested in studying the social structure of accumulation of the information economy.

I will show that this process of technological transition is interconnected with: changing modes of regulation; the state of competitive struggle between AT&T and its rivals; and the role of communications in regional integration and reconfiguration. In making these arguments, and in the formulation of econometric specifications, in addition to the obvious reference to empirical and theoretical literature concerning the telecommunications sector, I will draw principally upon two branches of economic theory : (1) theories of innovation diffusion; and (2) theories of regional development and restructuring.

The innovation process that forms the case study of this dissertation follows a developmental sequence determined by Local Exchange Carriers (LECs) for each of their geographic points of interface with their customers. Several fundamental research issues are raised by this process.

1. Do larger LECs exhibit a tendency to implement innovations more rapidly than smaller telecommunications firms?

2. Do dissimilarities in the modes of regulation operating in different states help to explain differential LEC behavior?

3. Is there a regional bias against peripheral areas?

4. How strong are economies of agglomeration in telecommunications innovation patterns?

While the interpretation of the first two industrial organization oriented questions are rather unambiguous, the rest hinge on definitional and measurement issues.

1.2 A Case Study of Spatial and Temporal Innovation Diffusion in the U.S. Telecommunications Sector

In this section I more fully describe the Equal Access process. I also present arguments concerning why a case study of the spatial and temporal diffusion of this particular telecommunications innovation is a worth-while and interesting research endeavor.

1.2.1 What is 'Equal Access'?

A key provision of the divestiture agreement which ended the Justice Department lawsuit against AT&T was that the Bell Operating Companies (BOCs) would be required to provide exchange access to all long distance companies "equal in type, quality, and price to that provided to AT&T" [3] . The provision of equal exchange access was ordered to be offered by every end office[4] by September 1 1986. Exceptions to this deadline were allowed for end offices that were not yet employing electronic switching equipment. The Federal Communications Commission (FCC) supplemented the stipulations of the *Modification of Final Judgment (MFJ)*[5] with further operational details including the requirement that every subscriber be offered the opportunity to designate a primary long-distance carrier[6].

The Equal Access provisions of the *MFJ* had refered to the Bell Operating Companies (BOCs), the LECs that had been part of AT&T prior to their divestiture. A consent decree between GTE and the Justice Department in 1984 extended these provisions to the GTE LECs. Judge Green of the U.S. District Court required the submission of a schedule detailing by end office the date by which transition to Equal Access capability would be accomplished. It is this schedule that will be the object of my econometric analysis. The geographical coverage of the switching stations included in the Equal Access schedule is shown in Table 1.1. Many of the smaller Independent (i.e., non-Bell) LECs that are included in the totals of columns one and two of the table, often do not submit Equal Access plans.

[3] United States v. American Telephone and Telegraph Co., 552 F. Sup. 731, (D.D.C. 1982).

[4] An end office, or wire center, is an office building containing the local switching systems to which customers are directly connected.

[5] The name stems from reference to the 1956 consent decree between the Justice Department and AT&T which was modified by the 1982 agreement among these parties.

[6] Under Equal Access, a primary long-distance carrier is accessed when the customer dials 1 and a long-distance number. Prior to divestiture, in order to obtain service from an AT&T competitor, it was necessary to dial 23 or more digits (a 7 digit company acccess number, plus a customer identification number, which was generally 6 digits, and only then, the ten digit long-distance number.

TABLE 1.1: Geographic Coverage of Equal Access Schedule

STATE	Number of Companies	Switching Stations Total	Switching Stations in Schedule	Percent
Alabama	34	371	188	50.7%
Arizona	14	264	116	43.9%
Arkansas	32	375	208	55.5%
California	23	1,225	876	71.5%
Colorado	28	308	125	40.6%
Connecticut	3	146	116	79.5%
Delaware	1	35	34	97.1%
District of Columbia	1	41	33	80.5%
Florida	14	555	424	76.4%
Georgia	35	469	293	62.5%
Idaho	24	197	77	39.1%
Illinois	59	1,090	726	66.6%
Indiana	47	614	441	71.8%
Iowa	153	831	618	74.4%
Kansas	42	586	181	30.9%
Kentucky	22	407	272	66.8%
Louisiana	20	345	229	66.4%
Maine	20	259	163	62.9%
Maryland	4	241	236	97.9%
Massachusetts	4	308	281	91.2%
Michigan	40	780	610	78.2%
Minnesota	94	723	232	32.1%
Mississippi	20	272	201	73.9%
Missouri	45	750	287	38.3%
Montana	18	287	25	8.7%
Nebraska	42	486	239	49.2%
Nevada	13	137	48	35.0%
New Hampshire	14	165	142	86.1%
New Jersey	3	341	232	68.0%
New Mexico	17	196	57	29.1%
New York	44	1,278	792	62.0%
North Carolina	29	538	325	60.4%
North Dakota	25	299	102	34.1%
Ohio	46	919	756	82.3%
Oklahoma	40	535	279	52.1%
Oregon	37	327	134	41.0%
Pennsylvania	38	903	579	64.1%
Rhode Island	2	43	36	83.7%
South Carolina	28	290	234	80.7%
South Dakota	32	263	109	41.4%
Tennessee	28	396	243	61.4%
Texas	64	1,510	942	62.4%
Utah	14	171	49	28.7%
Vermont	11	141	97	68.8%
Virginia	21	505	393	77.8%
Washington	26	422	210	49.8%
West Virginia	15	263	181	68.8%
Wisconsin	99	671	373	55.6%
Wyoming	12	92	10	10.9%
TOTAL	1,497	22,371	13,554	60.6%

Source:
(Col. 1-2) National Exchange Carriers Association Tariff 4 database
(Col. 3) AT&T Cutover Schedule database

The last column of the table shows by state[7] , the percentage of total switching stations included in the schedule. Based on information compiled by the National Exchange Carriers Association (NECA), as of the end of 1989, there were 22,371 switching stations of various vintages in operation in the 48 states and Washington, D.C. Table 1.1 shows that 60.6% of these end offices switches are included in the Equal Access schedule that forms one of the primary data sources for the proposed empirical analysis.

1.2.2 Why focus on Equal Access?

The transition to Equal Access is a noteworthy aspect of technological change in the telecommunications industry for a number of reasons. It is an event that sets in motion changes in the entire set of relationships constituting the social formation of this sector. Viewed through a neoclassical looking glass, the social and economic

[7] Alaska and Hawaii are included in the schedule but have been omitted from the table. The switching stations for these states, as well as for Puerto Rico and the Virgin Islands have been excluded because many of the variables to be utilized in the proposed empirical analyses are not available for these areas.

significance of Equal Access is seen to reside in the expansion of consumer choice alternatives. That is, the typical focus is on the consumer/inter-exchange carrier relationshi This is an inadequate perspective since many other important relationships are significantly impacted. For instance, one major repercussion of Equal Access implementation is that competition is intensified between AT&T and its rivals. Heightened competition and attendant declining AT&T market share, in turn, influences the regulatory relationship between the FCC and AT&T [8]. AT&T's loss of market share also potentially weakens the bargaining position of organized labor since most of the other inter-exchange carriers remain non-unionized. Another upshot of the implementation of Equal Access is that once the same quality of access to the local network is available to AT&T's rivals, the access charges that they pay to the LECs rise to the same rate level paid by AT&T for access. Once this significant cost advantage is eliminated, the willingness of the other common carriers to engage in fierce price competition is moderated.

Aside from the impact of this process on the telecommunications sector, this case study is also important for the opportunities it affords to advance the methodologies for analyzing the temporal and spatial patterns of diffusion processes within the context of an economy undergoing regional and sectoral restructuring. To my knowledge, no other study of innovation diffusion processes has utilized a dataset of comparable geographic coverage, at such a fine scale of spatial detail, for which both intra-firm and inter-firm comparisons can be made.

[8] As the 'dominant' inter-exchange carrier, AT&T is subject to more regulatory constraints than MCI, SPRINT, and other smaller competitors. For instance, only AT&T was subject to 'rate-of return' regulation, or currently to 'Price-Cap' constraints. Increasing loss of market dominance buttresses AT&T pleas for loosened regulation. The current chairman of the FCC, Alfred C. Sikes, is beginning to be responsive to these pleas. He is quoted as stating: "We now have a very competitive long-distance market, and I think it is time to revisit the rules that preceded the breakup of AT&T and to re-examine their legitimacy...I have no intention of bringing AT&T to its knees." [Nathaniel C. Nash, "Easier rules For AT&T Suggested," New York Times, 7 March 1990, p. D1]

Chapter 2

The Social Shaping of the U.S. Telecommunications Sector

2.1 Introduction

The purpose of this chapter is to place the Equal Access process, the subject matter forming the core empirical analyses of this dissertation, in an historical context. To adequately understand the equal access provisions and time-tables it is necessary to first understand the regulatory environment and market structures that where in place at the time of the divestiture agreement. Divestiture, in turn, is only understandable with knowledge of the historical backdrop.

The breakup of AT&T was preceded by a lengthly debate. The beginning of these intellectual conflicts is generally considered to have begun around 1959, at the time of the so-called "Above 890" decision which first allowed limited competition in the telecommunications service market. All the major segments of the Federal government participated in these arguments, including the judiciary, the legislature, and several cabinet level departments. Although the divestiture outcome rested more on the politics of events than the intellectual arguments, the latter played a large role. Furthermore, the US debates on telecommunications policy have had a major influence on the intellectual conflicts in other nations.

The main issue in the telecommunications policy debates concerned the form that the industry should take—regulated monopoly or competition. Before divestiture AT&T was the largest corporation in the world. The organization form issue at its core concerned the size and power of this corporation. One of the first issues in the associated debates was the appropriate conceptual framework. Namely, should regulatory or anti-trust legal doctrines apply (Allen 1990).

Two aspects of the process of change within the U.S. telecommunications industry's regulatory and market structures will be emphasized. First, although many analysts have emphasized the role of technological change, changing ideologies played a more dominant role. Deregulatory fervor prompted actions at critical points in the evolution of U.S. telecommunications policy. Second, the various policy changes had cumulative impacts. Actions taken at one time created or increased forces that would necessitate later resolution. The somewhat inevitable consequences of the forces set in motion seems not to have been apparent to most of the actors. There was a tendency to view each decision in isolation. One of the purposes of this brief account is, therefore, to pull seemingly disjointed events together to provide a synthesis that is more integrated than the contemporary perceptions. Over time, the inherent contradictions that the system was developing became more and more apparent. A climate was created that was well-disposed to fundamental structural solutions to the accumulating contradictions.

2.2 The New Deal Era Accommodations

2.2.1 The Communications Act of 1934

In 1932, as a part of an extensive strategy of reorganization of the executive branch, President Roosevelt sought the creation of a federal commission that would pull together the existing fragmented authority over commmunications. At the time of the act's passage, characterization of the telephone and telegraph industries as *natural* monopolies was the prevailing public policy perspective (Horowitz 1989, 123). The act reinforced preexisting industrial barriers between newspapers, radio broadcasting, telegraphy, and telecommunications. The corporations offering these communications services were confined to a single field of operation. The regulatory structure of the Federal Communicatons Commission (FCC), which was created by the Communications Act, essentially left intact, with limited modifications, the the earlier established institutional arrangements[1]. The creation of the FCC combined the telephone regulatory functions of the Interstate Commerce Commission (ICC) and the radio regulatory functions of the Federal Radio Commission into one institution. AT&T was authorized to exercise monopoly control over long-distance voice telecommunications and to control the local monopoly telephone operating companies that comprised the Bell System.

The basic accommodation was that in return for not interfering with the monopoly structure of the industry, the FCC could mandate a requirement to interconnect all independent carriers and to provide service to all requesting it, at a reasonable price, not directly linked to the high incremental cost of providing service in remote areas. The FCC viewed its basic regulatory responsibility as rationalizing the industry.

AT&T had adopted a strategy of opposing the creation of the FCC. In Congressional testimony in 1934, the AT&T president at the time, Walter S. Gifford, argued that AT&T had not been accused of abusive behavior and that the ICC had not received complaints about interstate telecommunications rates, nor had the ICC been accused of dereliction of its duties. He further argued against the creation of the FCC on the grounds that 98.5% of telephone traffic was local or intra-state long distance, which was subject to state regulation by public utility commissions (Stone 1991, 278). In contrast, David Sarnoff of RCA, at the time the most powerful radio network, enthusiasticly supported the creation of the FCC. The provision of the Communications Act concerning the licensing of all new applicants for radio stations, was in the interests of RCA in that it would increase entry barriers (Stone 1991, 279).

Although neither the Communications Act nor any FCC rules expressly granted AT&T monopoly status, from 1934 to the 1970s, the FCC unabashedly protected AT&T's monopoly position in several important ways.

- Firstly, it protected the corporation from competitive entry through its regulation of new telecommunications services and technologies.
- Secondly, the FCC did not develop a capability and means for effectively monitoring AT&T's price structures. Instead, AT&T rates were subject to an informal review process known as "continuing serveillance", rather than formal hearings requiring evidentiary justifications for rate adjustments.
- Thirdly, business risk was stabilized by guaranteeing a "fair" rate of return and by allowing long-term capitalization.

[1]The right of the Federal government to regulate interstate telecommunications, under the jurisdiction of the Interstate Commerce Commission, was established by the Mann-Elkins Act of 1910 (Horowitz 1989, 127).

2.2.2 The FCC's 1939 Study of AT&T

Prior to its enactment, preliminary drafts of the Communications Act gave the new regulatory commission jurisdiction over the contracts between AT&T and its subsidiaries, in particular, Western Electric. This provision was based on concern over excess profits arising from the spread between the manufacturing costs of Western Electric supplied equipment and the prices paid by the operating companies[2]. This resulted in both high profits on manufacturing and an inflated rate base for telecommunications operations. Rate regulation allows a "reasonable" rate of return on invested capital. The stock of invested capital of the Bell System, referred to as its rate base, included telephones and other equipment purchased by regulated telephone operating companies from unregulated Western Electric. The congressional committee drafting the legislation removed this provision and instead recommended that the FCC study the contracts and report back to Congress on whether further legislation was needed (Temin 1987, 14). The FCC study, based on two years of research and testimony, was submitted to Congress in 1939 and reported that Western Electric prices did not bear a reasonable relation to the costs of manufacturing. The report[3] became the basis for the Justice Department's 1949 antitrust suit against AT&T. The antitrust complaint alleged that AT&T and Western Electric conspired to monopolize the market in telephone equipment, excluded other manufacturers and sellers of equipment from the market, and resulted in monopoly profits.

2.2.3 The 1956 Consent Decree

A 1956 Consent Decree between the Justice Department and AT&T terminated the suit. The decree had the following provisions (Temin 1987, 15):

- Patents were required to be offered for licensing.
- Western Electric was restricted to manufacturing only equipment used in telephony.
- The Bell System operating companies were limited to provision of common carrier communications services.

In his account of the events leading to the divestiture of the BOCs from AT&T, Coll, in a chapter entitled "Legacy of a Scandal", recounts that many of the staff lawyers in the Antitrust division of the Department of Justice felt that "AT&T had abused its political power, circumvented the legal process, and cheated the American public (Coll 1986, 59)" by the behind the scenes deals made with the Eisenhower administration to settle the case. Coll argues that this sense of betrayal led to the close monitoring of AT&T by the Antitrust Division in the 1960s that provided the basis for the 1974 antitrust suit that ultimately resulted in the divestiture.

[2]Western Electric began supplying the Bell telephone companies with equipment in 1882. With the exception of some parts patented and controlled by other companies, Western Electric was the exclusive provider of telephone equipment to the Bell System companies. Other smaller companies were forced to limit their market to the independent telephone companies.

[3]The investigation produced 60 volumes of transcripts and over 70 volumes of staff reports. From this record two reports were prepared. The first, made public in April 1938, entitled *Proposed Report–Telephone Investigation*, did not have the support of the majority of the FCC commissioners. A substitute *Report on the Investigation of the Telephone Industry in the United States* was the one submitted to Congress in April of 1939, differing from the first primarily in regard to recommendations for future regulation (Danielian 1939).

2.3 The Erosion of AT&T Hegemony

2.3.1 Hush-A-Phone

In Hush-A-Phone, a case generally ridiculed after the fact, AT&T tried to prevent a non-Western Electric piece of equipment from being attached to the network. Hush-A-Phone was a piece of plastic to hook over the mouthpiece. It was claimed to increase privacy and reduce the effect of extraneous noise, enabling more private conversations in crowded office conditions. "Foreign attachments" was an industry term for devices that terminate a telephone wire on the customer's premises other than a standard Bell System telephone receiver. AT&T had a complete prohibition against non-Bell attachments, on the ground that foreign attachments posed a threat to the technical integrity of the phone system. It was argued that malfunctioning foreign devices could harm the network. In 1948, the Bell Operating Companies notified distributors and users of the Hush-a-Phone device that the device violated AT&T tariffs. Whether or not the threat was genuine, the blanket prohibition served AT&T's economic interests well. The prohibition on foreign attachments was a manner of establishing entry barriers to the manufacturing of telephone equipment. The licensing provisions of the 1956 Consent Decree and the expiration of patents had weakened such barriers to entry. The Hush-a-Phone Corporation petitioned the FCC to disallow the prohibition. In 1955, the Commission upheld AT&T's positon, on the grounds that "unrestricted use of the Hush-a-Phone could result in a general deterioration of the quality of interstate and foreign telephone service." Not surprisingly, the company applealed this decision. In 1956, the same year as the Consent Decree in *U.S. v. Western Electric*, the Court of Appeals set aside the FCC's order, applying a standard of "private benefit without public detriment (Vietor 1989, 39)."

2.3.2 Carterfone

AT&T responded by allowing mechanical attachments but maintaining restrictions on electrical devices. This ban was challenged by the *Carterfone* case.

Between 1959 and 1966, the Carter Electronics Corporation of Texas manufactured and sold a device that permitted direct voice communications between someone using the telephone network and someone with a modile radio. A telephone receiver, placed on a cradle in the Carterfone, effected an inductive connection between the telephone line and mobile radio channel. This satisfied a market demand for remote telecommunications for such activities as offshore drilling, oil field operations, and ranching.

Whenever a BOC discovered a subscriber using a Carterfone, service would be discontinued in compliance with the foreign attachment restrictions in their tariffs. In 1965, after unsuccessful negotiations with AT&T, Carter filed an antitrust suit seeking an injunction and treble damages. The Court referred the case to the FCC on the basis of primary jurisdiction. The FCC held that the restrictions had been "unreasonable, discriminatory, and unlawful" and that the prohibitions should be removed. The FCC ruling was made in the context of the precedent of the Hush-a-Phone decision and rumblings at the Justice Department that AT&T tariff provisions against foreign attachments were in violation of antitrust laws.

This decision opened the customer premises equipment market to entry. Manufacturers of standard telephones, decorator phones, recorders, chimes, headsets, key sets, PBXs, teleprinters, and modems entered the market. AT&T reacted to the decision by stipulating in its tariffs that all foreign attachments had to be first connected to "protective coupling" devices manufactured by Western Electric (Horowitz 1989). The Justice Department subsequently alleged these devices to be over-engineered and excessively expensive. They had to be installed by BOC's on a leased basis, regardless of any threat of harm (Vietor 1989, 40–41).

In 1972, the FCC adopted a program of certification based on detailed technical standards, in lieu of protective devices.

2.3.3 The *Above 890* Decision

In a case formally called *In the Matter of Allocation of Microwave Frequencies in the Band Above 890 Mc.*, the FCC authorized the establishment of new private line communication services based on the use of microwave technology (using frequencies above 890 megahertz in the radio spectrum). The salient issues were both economic and technical (Vietor, 1989, 44)

1. Was the FCC obligated to protect common carrier companies from any deliterious economic effects that the carriers might suffer from the operation of point-to-point systems?

2. Did private point-to-point communications systems depend for their viability on interconnection with common carriers?

3. What was the demand and supply outlook for radio frequencies, and would the new systems cause interference or terminal congestion?

4. Should shared use of private point-to-point systems be permited?

In hindsight, this FCC decision is generally viewed as being the first major challenge to the monopoly character of the telecommunications industry. Strong lobbying for this decision came from an alliance of manufacturers of microwave equipment, and large, geographically dispersed corporations that could benefit from a lower priced competitive service that would enable them to quickly communicate with their various operating units. The FCC failed to be persuaded by AT&T arguments of congestion to the airwaves, threats to national security, and significant financial loss to existing common carriers. The FCC maintained that competition from microwave systems would foster innovation in both telecommunications service and equipment (Horowitz 1989, 225).

Although the decision had little immediate effect on the industry, it set in motion a chain of unforeseen consequences. First, *Above 890* paved the way for ensuing decisions that would open entry much more widely to other specialized telecommunications services.[4] Second, AT&T's aggressive response to *Above 890* was to engage in practices that became the basis for later antitrust litigation and FCC proceedings.[5]

[4] The FCC, however, as Kahn has pointed out, was by no means prepared at the time to authorize additional competition in the common-carrier communications business itself, or to commit itself to a policy of unrestricted competitive entry without regard to the possibility of an unfavorable impact on the carriers and their other customers.

[5] The threat of its major corporate customers building their own private systems led AT&T to institute a bulk private line discount service called "TELPAK." Prodded by charges from Western Union and Motorola (a potential suppliers of microwave equipment) that AT&T priced TELPAK rates artificially low, the FCC initiated a series of proceedings on AT&T's tariffs. The FCC lacked sufficient data to make a determination as to whether TELPAK rates covered the costs of providing the service. However, the TELPAK rate controversy became part of a general inquiry on AT&T rate determination. These protracted investigations later were consolidated into a proceeding known as "Docket 18128." In 1976 the FCC ruled that the TELPAK rates and de-averaged private line tariffs were unlawful.

Above 890 brought out into the open the two power blocs promoting the liberalization of common carrier entry regulations (Horowitz, 1989, 226). One of these blocs was obviously the potential competitors to AT&T. Somewhat less obviously were the heaviest corporate users of telecommunications services. The push of these two blocs was pursued at every propitious moment over ther twenty-five year period leading up to divestiture.

2.3.4 The MCI Decision

In 1963, MCI, a small and underfinanced company, applied for a permit to construct a microwave link between Chicago and St. Louis to meet the interoffice and interplant communicatons needs of small businesses. The private systems permitted by *Above 890* effectively could be built by very large users only. The MCI private line system was reputed to be more technically sophisticated, flexible and lower cost than AT&T offerings. Furthermore, the system enabled use by small businesses because of channel sharing arrangements. The proposed MCI private line system would not connect subscribers into the telephone system local loop.

Because of both the potential ramifications of the case and the ardent lobbying of the Bell System to reject the MCI proposal, the FCC did not announce a decision until 1969. In approving the MCI application (by a close vote of 4 to 3), the Commission argued that MCI would be only serving a latent market. The Commission also felt that their decision was a practical response to complaints from computer service companies about deficient communications capacity. The decision occurred in a climate of a growing anti-big-corporation ethos. In this environment, MCI shrewdly began to portray itself as a telecommunications David against the AT&T Goliath.

In its MCI decision, the FCC did not resolve the critical economic question. Namely, would the entry of MCI and other such firms, result in sufficient injury to the common carriers that a higher-cost, lower quality communications service to all other users would be inevitable? Its decision made the clear case for competitive entry: a new firm, seeing a market not thus far tapped, is willing to risk its capital to bring in a new, lower priced-quality combination. But if the telecommunications network is really a natural monopoly, the indirect costs and inefficiencies imposed on the entire system by such entry could outweigh its direct benefits. This was the real burden of the carriers' opposition: they claimed that MCI propose to engage in mere creamskimming, throwing on them and their other customers the costs thereof (Kahn 1988, 134).

The concept of access charges is the culmination of more than a decade of court decisions and FCC rulemarkings concerning the rights and terms of local exchange interconnection by new interexchange carriers. Following the FCC's *Specialized Common Carrier* decision in 1971, which established an overall policy favoring entry in the interstate private line market, MCI alleged in 1973 that the BOCs were either refusing to provide it with the same local exchange interconnections as provided to AT&T Long Lines, or in some cases, not furnishing any interconnection services. Taking its interconnection dispute with AT&T to court, MCI prevailed, although the order to interconnect was vacated on appeal pending FCC review of the issue. In 1974, the FCC asserted sole jurisdiction over interstate private line carriers, which made unnecessary approval for interconnection by state regulatory commisssions, the basis for AT&T's initial refusal to interconnect with MCI. The FCC then ordered AT&T to interconnect with MCI for all private line services (Bolter 1984, 346).

2.3.5 Specialized Common Carrier

Not unexpectedly, following the MCI decision, the FCC was swamped with requests to authorize construction of private line systems for hire. The Commission's *Specialized Common Carrier* proceeding was initiated as a forum for the formulation of general policy. Two basic arguments were made in support of permitting entry into the specialized communications field. Firstly, it was argued that entrants would offer new services to customers with needs that had not been fulfilled by the existing carriers. The other main argument was that liberalization of entry could provide a potential basis of comparison for use in rate determination cases. It was further argued that competitive pressures would stimulate innovation as well as speedup the introduction of new technology (Horowitz 1989, 228).

Specialized Common Carrier required AT&T to permit the new competitors access to the local telephone exchanges at reasonable terms. AT&T initially instituted a policy of denying interconnectivity. In 1974 a Federal courts decided that AT&T had to provide its private line competitors with the same types of facilities that it provided to its own private line operations. AT&T responded by permitting interconnection but encumbering them with restrictions and imposing new tariffs on the specialized carrier companies.

2.3.6 Domestic Satellites

From the very outset, the intense political struggle over who would be authorized to put up and operate the satellite system was clearly envisaged as determining whether this new communications medium would develop as an integral part of the operations of the existing common carriers or whether, instead, it might develop independently of, and in direct competition with them. Proponents of the latter position argued strenuously that if the carriers, and preponderantly AT&T controlled the satellite system, they would restrain its development in order to protect their huge investments in existing facilites. They also made much of the Bell System's expressed skepticism about the commercail feasibility of the new techniques and of its preference for the low-level, random, moving satellites, which would (and in fact did) prove to be much more expensive than the 22,300-mile high synchronous satellites now being used (Kahn 1988, 136). In the international field, AT&T had a monopoly on message telephone and voice-grade channel service.

The result was a compromise. In 1962 Congress entrusted the international field to the Communications Satellite Corporation, a separate, newly established company whose ownership was to be divided equally between the common carriers on the one hand and the investing public on the other, with only six members of its Board of Directors to represent each of these two constituencies and another three to be appointed by the President, and with the further provision that no stockholder could elect more than three directors.

2.3.7 The Execunet Decision

The Execunet decision was the turning point which finally opened the US telecommunications industry to full competition. In Execunet, a federal court reversed an FCC decision, and MCI and the other firms that came to be known as Specialized Common Carriers were thereby allowed into AT&T's core market, namely, Message Toll Service (switched long distance service).

In 1975, MCI filed a tariff with the FCC for a new shared private line service that it called "Execunet." AT&T pointed out to the FCC that Execunet was functionally equivalent to AT&T's Message Telecommunications Service (MTS)—i.e., its regular long distance service— except that the long distance transmission segment of the telephone call was routed over MCI's own transmission facilities. MCI replied that Execunet was an innovative private line service. The FCC, however, sided with AT&T's view that it was essentially MTS. The FCC rejected the MCI tariff as unlawful and ordered MCI to stop offering the service. The FCC observed that MCI's authority as a specialized common carrier was limited to the offering of private line services, not switched message services. On appeal of the FCC's decision, the D.C. Circuit Court granted a stay in the termination order and, at the FCC's request, remanded the case back to the FCC for further consideration. On reconsideration, the FCC again decided that Execunet was not a private line service, affirmed its decision reached a year earlier in June, 1976, and again rejected MCI's tariff for Execunet service (Bolter 1984, 347).

MCI appealed the FCC's decision to the D.C. Circuit Court. In July 1977 the court ruled that the FCC's *Specialized Common Carrier* decision did not restrict MCI to offering only private line services. The court sustained the FCC's authority under Section 214 and Title III of the Communications Act of 1934 to place service restrictions on common carrier facility authorizations. The court held, however, that the FCC cannot impose such restrictions until it first determines whether the "public interest, convenience and necessity" require them. Since the FCC had not made an affirmative determination that an AT&T monopoly of the interstate switched service market was in the public interest, the court held that the FCC could not restrict the use of MCI's facilities that would limit MCI to providing only private line services. The court held that MCI could offer Execunet on its existing and authorized facilities but was not necessarily entitled to extend Execunet service on new facilities that were yet to be authorized and constructed.

The FCC appealed the Circuit Court ruling to the Supreme Court. In January 1978 the Supreme Court decided not to review the case. In February 1978 the FCC upheld AT&T's contention that the Circuit Court's Execunet ruling did not mandate AT&T to interconnect its local exchange facilities with MCI to originate or terminate its Execunet service. The FCC reasoned that it would first need to make an affirmative determination that Execunet was in the public interest before ordering AT&T to interconnect its local exchange facilities for MCI's Execunet service. This public interest determination would be based on the record developed in a new proceeding just initiated to address the general issue whether interstate switched message service should be provided on a basis free from direct competition. MCI appealed the FCC's decision to the D.C. Circuit Court. In April 1978 the court reversed the FCC's decision and ordered that AT&T furnish local exchange interconnection for MCI's Execunet service. Both AT&T and the FCC filed appeals of the Circuit Court ruling with the Supreme Court, but in November 1978 the Supreme Court declined to review the Circuit Court's decision (Bolter 1984, 347).

AT&T's legal obligation to interconnect its local exchange facilities with MCI as imposed by the D.C. Circuit Court's Execunet ruling had economic implications much more far-reaching than the decisions of the FCC and the courts mandating local exchange interconnection with the private line services of the specialized common carriers. With the specialized carriers' right to interconnect their interstate switched service with the BOCs now firmly established, the issue of the price of such local exchange interconnection required resolution. This issue was particularly sensitive, since AT&T's interstate rates for MTS and Wide Area Telecommunication

Service (WATS)—a bulk discounted version of MTS —recovered, in addition to the direct costs of long distance transmission, a portion of the costs of "jointly used" local exchange plant assigned to the interstate jurisdiction by the separations process. The appropriate pricing of local exchange access for interconnecting the specialized common carriers following the Execunet court opinion quickly expanded into a debate over traditional methods of pricing and cost recovery in the domestic telephone industry (Bolter 1984, 348).

2.3.8 Computers and Communications Decisions

As innovation, new entry, and competition reshaped equipment markets, it became increasingly difficult to distinguish the communications functions from the data processing functions that the equipment provided. This blurring of product-market boundares posed a dilemma for common-carrier regulation and antitrust enforcement. For AT&T, constrained by the 1956 consent decree, this blurring gave rise to incredibly complicated strategic and organizational problems (Vietor 1989, 42).

In its First Computer Inquiry, begun in 1966, the FCC addressed two fundamental questions: (1) whether data processing services should be subject to regulation, and (2) whether common carriers should be permitted to engage in data processing. At the time, the Commission settled on a definitional standard, based on a criterion of relative use. In 1971 the FCC adopted the following rules. It would not regulate pure data processing or hybrid services where message-switching was an incidental feature of an integrated data processing service. It would, however, regulate hybrid services in which data processing was incidental to message-switching functions. Furthermore, common carriers could only provide data processing services if they did so through a separate corporate entity.

Almost immediately after issuing its rules, the FCC realized that technological and market developments had combined to make the definitions and regulatory schemes of the First Computer Inquiry out-of-date. In its Second Computer Inquiry, the FCC adopted a new and simplified definition that distinguished between "basic" and "enhanced" services. The former was limited to the telecommunications service offering of transmission capacity for transporting information. Enhanced service combined basic service with processing applications that acted upon the format or content of the information. Common carriers were permited to provide enhanced services, but once again, only through separate subsidiaries. Realizing that classification schemes for distinguishing among various types of customer-premise equipment were becoming increasingly arbitrary, the Commission adopted a landmark decision in April 1980, known as Computer Inquiry II, that completely deregulated and de-tariffed customer-premise equipment (Vietor 1989, 43).

Shortly after the Computer Inquiry II ruling, divestiture released AT&T from the terms of the 1956 Consent Decree. For the Justice Department, the imposition of separate subsidiaries on AT&T made less sense after divestiture. For AT&T, it imposed a serious organizational handicap in its efforts to sell integrated services competitively. Digitization of long distance and local exchange networkds, making possible an array of new services and equipment was blurring the distinction between basic and enhanced services faster than the FCC could implement its rules.

The FCC undertook a Third Computer Inquiry, and announced its decision in June 1986. The Commission concluded that with bypass technologies proliferating and competition increasingly robust, the threat of corss-subsidy was receding. It ruled that structural safeguards could be replaced by non-structural safeguards, of which the most important was the implementation of "open network architecture".

Access to local and inter-exchange networks would be fully unbundled from competitive services and products by the provider, and made available on equal technical and pricing terms to any potential user (Vietor 1989).

With respect to computers and communications, the 1956 Consent Decree between the Department of Justice and AT&T separated telecommunications from computers, leaving AT&T limited to the former. The First Computer Inquiry confirmed the separation that had been established in the Consent Decree, and determined that while telecommunications was regulated, computers would not be. The Second Computer Inquiry tried its hand at making a different cut, through creating a different demarcation line between, computers and communications. "Basic" telephone service would remain regulated, but "enhanced" services could be provided by unregulated separate subsidiaries.

2.3.9 ENFIA

Exchange Network Facilities for Interstate Access was the first version of access charges, before AT&T's long lines were unbundled from its local operations by divestiture.

So called Other Common Carriers (OCCs), such as MCI, were first provided with a basic switched access arrangement referred to as Exhange Network Facilities for Interstate Access (ENFIA). Three types of ENFIA access arrangements evolved. ENFIA A, the first and most cumbersome, provided line-side connection and a local 7-digit access code to reach the OCC. ENFIA B provided direct end-office to OCC access. ENFIA C provided a trunk-side connection and a 950-10XX access code to reach the OCC designated by the XX digits. The ENFIA arrangements evolved into the "Feature Group" offerings specified in National Exchange Carriers Association (NECA) tariffs. Feature Group A, the counterpart of ENFIA A, provided line side connection and required a local 7-digit access code. Feature Group B is a trunk side connection with access through a 950-0/1XXX access code. Feature Group C was an interface to only AT&T through a trunk side connection, requiring only 1+ or 0+ access codes. This feature group ends when Equal Access is provided. Feature Group D, is Equal Access, trunk side connection with access according to presubscription, or via a 10XXX access code. OCCs receive a 55% discount for nonpremium Feature Group A or B access. When an office is equipped for Feature Group D access, the discount ends (Network Planning Subcommittee 1986, 6).

The various technical specifications for modifications to SPC switching systems go far beyond the basic legal requirements for the technical nature of Equal Access. Due to differing interpretation of legal requirements or underlying technical capabilities or limitations of particular switching systems, different manufacturers' equipment embody Equal Access capablility with some variation.

2.3.10 Competitive Common Carrier

The *Competitive Common Carrier (CCC)* proceedings of the FCC resulted in differential or asymmetric regulation of AT&T, relative to its new competitors. Differential regulation, introduced by the FCC in 1979, was the policy of retention of stricter, more costly, regulatory requirements for AT&T, from which the other firms in the long-distance market were exempted. The *CCC* proceeding classified carriers as "dominant" or "non-dominant". The streamlined regulation of "non-dominant" firms consisted of:

- No requirement to cost justify tariffs.

- Acceptance of tariffs without question unless complaints were filed. Parties seeking the suspension of a tariff would need to show, among other demonstrations, that there be a high probability that an FCC investigation would find the tariff to be illegal, and that the proposed tariff would result in "irreparable injury" to the harmed party.
- Reduction of the notice period prior to tariffs becoming effective from 90 days (for rate change filings) or 70 days (for other tariff changes) to 14 days.
- No requirement for filing annual financial information.
- Granting blanket approval of new construction plans (rather than line-specific approval of investment plans).

In contrast, AT&T, the "dominant" carrier:

- Remained subject to rate-of-return regulation.
- Had to file cost justifications for new tariffs.
- Had to obtain licenses for construction of transmission lines and before discontinuance of service.

2.4 The Breakdown and Reconstitution of Institutional Formations

A document of the U.S. District Court for the District of Columbia, known as the *Modification of Final Judgment (MFJ)*, contains the terms that ended the antitrust suit originally filed against AT&T in 1974, in exchange for the divestiture of the BOCs from AT&T. For the purposes of this dissertation, however, the most relevant aspect of the *MFJ* concerns the requirements regarding the provision of "equal access". The *MFJ* is so called because it modified the terms of the Consent Decree of 1956, known as the Final Judgment, which ended the earlier Justice Department antitrust suit against AT&T begun in 1949. It required AT&T to submit to the court within 6 months, a detailed plan of reorganization regarding the requirements included in the *MFJ*. It also established an 18 month deadline for implementation of the requirements. Saving the description of the details regarding equal access that are presented in the *MFJ* for last, the key aspects of the agreement were:[6]

1. The transfer from AT&T to the BOCs of "facilities, personnel, systems, and rights to technical information" that would enable the BOCs to perform their exchange telecommunications and exchange access functions independently of AT&T.
2. The definition of what in the plan of reorganization were called Local Access and Transport Areas (LATAs), but which in the *MFJ* are "exchange areas". These geographical areas comprising BOC service territories were to be established according to the following criteria:
    - Each area should encompass contiguous local exchange areas that served "common social, economic, and other purposes", and could exceed municipal and local government boundaries.

[6] This section is based on the copy of the *MFJ* printed as an appendix to Tunstall's *Disconnecting Parties* (Tunstall 1985).

- Each area would normally be made up of one standard metropolitan area (or consolidated statistical area for densely populated states).
- Areas should normally not cross state boundaries.

3. The separtion within BOCs of equipment and personnel used for inter-LATA services from those used for intra-LATA services. Joint ownership of facilities by AT&T and the BOCS was prohibited.

4. The termination of license contracts between AT&T and the BOCs, and between Western Electric and the BOCs.

5. A spin-off of stock of the separated BOCs to AT&T shareholders corresponding to the AT&T assets transferred to the BOCs.

6. The BOCs were prohibited from discriminating in favor of AT&T, relative to other long distance carriers, with regard to:
   - Purchase of products or services.
   - Dissemination of technical information.
   - Provision of new services and the planning for or construction of new facilities.

7. The BOCs were not permitted to:
   - Offer inter-LATA telecommunications services.
   - Manufacture or provide telecommunications products or customer premises equipment. This ban was lifted several years later.

8. The BOCs were permitted, but not required, to offer to provide billing services on behalf of long distance carriers.

9. Each BOC was required to provide all long distance carriers exchange access on a tariffed basis that would be "equal in type, quality, and price to that provided to AT&T and its affiliates. An appendix to the *MFJ* specified the timetable for phasing-in equal access.
   - Each BOC should begin offering equal access no later than September 1, 1984. Every end office, with some permitted exceptions, were to offer equal access no later than September 1 1986. Exceptions to the deadline, which were supposed to be for the minimum time necessary, were allowed in the following circumstances:
     - End offices not using electronic, stored program control switches.
     - End offices serving fewer than 10,000 access lines.

The *MFJ* became effective July 1 1982. The other key dates were submission by AT&T to the Department of Justice and Judge Greene of the US District Court of a Reorganization Plan on January 1 1983 and implementation of the plan beginning January 1 1984. The main issues that the reorganizational plan needed to address were:

- Personnel considerations, including staffing, benefits, training, and labor relations issues.

- Financial and technical issues relating to the assignment of assets to the new corporate entities.

- The corporate structure of the undivested components of AT&T (principally Long Lines, Bell Laboratories, and Western Electric).
- Suggested formulas for access charges (the rates to be charged to long distance carriers for provision of access to local networks).
- The post-divestiture reorganized form of the BOCs.
- The definition of the geographical boundaries of LATAs.

For the purposes of this dissertation, it is the latter two issues that are most relevant.

2.5 The Regional Dimensions of State and Federal Policies

2.5.1 Jurisdictional cost allocation

A 1930 Supreme Court case, *Smith vs. Illinois Bell Telephone Co.*, became a landmark in the history of jurisdictional cost allocation practices and ratemarking in the telephone industry. Prior to this decision, the Bell System contended that local exchange rates should recover the cost of subscriber station equipment, local distribution plant, and local exchange switching equipment. Toll rates, according to the Bell System, should recover only the costs of toll switching equipment and interexchange switching and transmission facilites. The term "board-to-board" comprehended those facilities emanating from the trunk side of the originating local switchboard through the terminal side of the terminating toll switchboard. During the early part of the century, the technology of telephony was such that toll and local exchange facilities were more or less separate and discrete, which made a board-to-board separation of costs between local and toll service reasonable straight-forward.

The *Smith* decision, however, supported a competing theory of jurisdictional cost allocation, the "station-to-station" principle of cost allocation. From this viewpoint, all telephone plant from the originating to the terminating customer's phone equipment, including local loop plant and local switching, is necessary to the completion of a long distance call. To the extent that no portion of the costs of exchange facilities is included in toll rates, then the local exchange rate payer is subsidizing the toll (or long distance) user. In the *Smith* decision, the Supreme Court rejected the argument of the Illinois Bell Telephone Company that a station-to-station jurisdictional separation of local exchange costs was too difficult. The case has been commonly interpreted as providing the basis for adopting "relative use" as the method of allocating some portion of local exchange plant investment and expenses to the interstate jurisdiction. Application of these principles to the jurisdictional allocation of costs proved workable so long as the industry remained closed to competition (Bolter 1984, 356).

The FCC and state public utility commissions jointly developed a system of ratemaking. "Separations" was the name of the procedures by which regulators divided assets and costs between the interstate and intrastate jurisdictions. "Settlements" was the term for similar averaging procedures worked out between AT&T and independent telephone systems. "Separations and settlements" constituted procedures by which the AT&T parent company paid local telephone operating companies for handling the local-exchange ends of long-distance traffic.

Between 1935 and 1937, the FCC negotiated a series of interstate rate reductions with AT&T. In 1939 the FCC proclaimed the principle of nationwide rate averaging whereby interstate calls of the same distance would be charged equally, regardless of the actual costs of routing. Rate averaging fulfilled the Commission's mandated responsibility to prevent rate discrimination. It also greatly simplified the separations problem because it required only the determination of aggregate interstate costs (Horowitz 1989, 134).

Begining during World War II, pricing began to be done in a way that would have a profound effect in later years. At the same time that the technology advances coming about from Bell Lab's R&D led to falling long distance costs, long distance prices remained relatively high. The resulting financial surplus was used to keep local rates relatively low. This situation has been described as a cross-subsidy from long distance to local prices. The mechanism for achieving this cross-subsidization was the financial accounting arrangements whereby the joint costs of local and long distance operations were allocated (Allen 1990, 5).

Under the traditional rate-of-return approach to regulatory accounting, the separations process loaded some of the costs of local onto long distance. When calculating the revenue requirements for long distance with the loaded costs included, higher rates resulted. Surplus revenues could then be flowed back to "subsidize" local operations. The gap between the costs and the pricing structures of long distance created a financial incentive for competition.

2.5.2 The Ozark Plan

In 1970, state public utility commissioners successfully negotiated a new plan for separations and settlements, that became known as the "Ozark Plan". The new cost allocation methodology changed existing practices by shifting more of the recovery on non-traffic-sensitive costs from local to toll rates. This had the effect of lowering local telephone rates since the increasing revenues paid to the local telephone operating companies by AT&T long distance, meant lower revenue requirements from internal sources (Horowitz 1989).

2.5.3 Restructuring of the BOCs

The Consent Decree left open the form of reorganization of the BOCs. Among the range of alternatives were:

1. Keep each of the 22 BOCs as an independent company.
2. Divide the 22 BOCs into 48 companies, one for each of the contiguous states.
3. Group them into regional holding companies.
4. Consolidate them into one nationwide holding company.

The study group that considered the alternatives, made up of 5 BOC presidents and the vice-chairman and chief financial officer of AT&T, settled on the regional restructuring framework. They continued to deliberate on the optimal number for some time, considering between 4 to 8 regional entities. According to one of the participants, the group's deliberations were guided by the following types of considerations (Tunstall 1985, 119). Primarily for administrative simplicity, there was a strong consensus that no BOC should be split. Financial market consequences argued in favor of large holding companies, and that each be of approximately equal size (in terms of such indicators as assets or access lines). Having the regional companies jurisdictions span many states would mitigate regulatory risk. Avoidance of the spectre of continuing antitrust litigation based on size and power provided a logical basis for a larger number of companies. The seven-region model prevailed, comprised as follows:

- **AMERITECH**
  - Illinois Bell (IL).
  - Indiana Bell (IN).
  - Michigan Bell (MI).
  - Ohio Bell (KY, OH).
  - Wisconsin Telephone (WI)
- **BELL SOUTH**
  - South Central Bell (AL, KY, LA, MS, TN).
  - Southern Bell (FL, GA, NC, SC).
- **Bell Atlantic**
  - Bell of Pennsylvania (PA).
  - Diamond State Telephone (DE).
  - The Chesapeake and Potomac Companies (MD, VA).
  - New Jersey Bell (NJ).
- **NYNEX**
  - New England Telephone (MA, ME, NH, RI, VT).
  - New York Telephone (NY)
- **Pacific Telesis**
  - Pacific Bell (CA).
  - Nevada Bell (NV).
- **Southwestern Bell**
  - Southwestern Bell (AR, KS, MO, OK, TX).
- **USWEST**
  - Mountain Bell (AZ, CO, IA, ID, MT, NM, OR, UT).
  - Northwestern Bell (MN, NE, ND, SD).
  - Pacific Northwest Bell (ID, OR, WA).

As shown in Table 2, each of the regional holding companies had over $15 billion in assets, averaged $8.5 billion in revenue, and had 75,000 or more employees.

In addition to the creation of the regional holding companies, a central services organization, called Bell Communications Research, was formed from employees and assets of Bell Laboratories, Western Electric, and AT&T General Departments. The main purpose of this organization was the continuing development and maintainance of the centrally developed operational and adminstrative systems needed for such functions as service order entry, circuit provisioning, billing, directory information, operator service systems, network planning, quality asurance, and engineering support.

TABLE 2.1: Regional Companies at Divestiture (Jan. 1 1984)

Company	*Assets*	*Revenues*	*Employees*
	(millions of dollars)		
AMERITECH	$16,257	$8,344	79,000
Bell Atlantic	$16,264	$8,323	80,000
BELL SOUTH	$20,809	$9,799	99,100
NYNEX	$17,389	$9,825	98,200
Pacific Telesis	$16,191	$8,082	82,000
Southwestern Bell	$15,507	$7,755	74,700
USWEST	$15,054	$7,437	75,000
TOTAL	$117,471	$59,565	588,000

Source:
W.B. Tunstall. *Disconnecting Parties.*
New York: McGraw-Hill, 1985. p.130.

2.5.4 LATAs

The *MFJ* restricted the divested operating companies to providing services within exchange areas. The long distance carriers, AT&T and its competitors, would serve interexchange traffic. The definition of the geographical subdivisions of the service territories of the operating companies–within which telecommunications services would be provided by the operating companies– and between which, services would be provided by the long distance carriers, entailed an intense process of negotiation. The term that was coined to refer to these geographical units, and introduced in the *AT&T Plan of Reorganization*, was "Local Access and Transport Areas" or "LATAs." The *MFJ* had specified the following principles for guiding the definition of these areas. Firstly, the areas should be homogenous in relation to a common social, economic, or related purpose. In urban areas, they were generally supposed to comprise one standard metropolitan area (SMSA). Except in special circumstances, they were not permitted to cross state boundaries.[7] In the pre-divestiture period, the Justice Department permited AT&T to establish, subject to Court approval, the definition of LATA boundaries. Based on some casual graphical inspection by a Justice Department lawyer of some AT&T provided calling data, a further quantitative criterion was adopted whereby a minimum LATA size needed to be between 100,000 to 125,000 subscribers (Temin 1987, p. 298). In addition to these considerations, a number of engineering issues were also relevant. LATA definitions needed to take into consideration existing network configurations. One underlying objective in specifying the LATA divisions was minimization of the costs of reconfiguring the network. For this reason, the court granted a number of exceptions to the *MFJ* position that LATAs should not cross state lines. For instance, the St. Louis LATA contains the Missouri and Illinois portions of the St. Louis–East St. Louis metropolitan area. For similar engineering and cost considerations, the court also permitted two exceptions, known as "corridor exemptions" to the *MFJ* restriction barring the regional companies from providing interLATA services.[8]

[7]To complicate matters, in the period in which LATA boundaries were being determined, the U.S. Office of Management and Budget (OMB) redefined SMSAs and Metropolitan Statistical Areas (MSAs).

[8]The two corridors were: (1) Between the 212 area code in New York to the 5 New Jersey counties on the other side of the Hudson River (Bergen, Passaic, Essex, Hudson, and Union); and (2) between the Philadelphia LATA and the Delaware Valley LATA in New Jersey (Burlington, Camden, and Gloucester counties).

TABLE 2.2: LATAs by Regional Holding Companies (April 1984)

Company	*Number of LATAs*
AMERITECH	29
Bell Atlantic	19
BELL SOUTH	38
NYNEX	12
Pacific Telesis	12
Southwestern Bell	27
US WEST	27
TOTAL	164

Source:
C.L. Weinhaus and A.G. Oettinger. *Behind the Telephone Debates*. Norwood, NJ: Ablex Publishing Corporation 1988. page 129.

An initial plan of 161 LATAs was submitted to the Court in October 1982. The final specification of the number and boundaries of LATAs was somewhat tentatively settled in April 1983 by Judge Greene, taking on a role of a type previously the prerogative of the FCC.[9] Table 3 shows the number of LATAs for each regional holding company.

The *AT&T Plan of Reorganization* also introduced the term "point-of-presence (POP)" defined as:

> a physical location where there is a point of interface between the BOC facilities providing a LATA access function and an interLATA carrier's facilities providing an interLATA function. A POP must be located within the boundary of the LATA being served, and it may contain an interLATA carrier's switching system or some other designated facility.[10]

In other words, each long distance carrier would have at least one facility in every LATA to give their customers access to and from that LATA.

2.5.5 Access Charges

Even before divestiture, the system of jurisdictional separations and settlements that subsidized universal service, had been unraveling. Competition in the long distance markets, as pointed out above, had led to an aggressive response from AT&T in the form of its ENFIA tariff. Bypass[11] of the local exchange by large users had begun to eat away the revenue base of the public switched network. Some large end-users bypassed both the local exchange at the orginating end of a calling location and the local carrier at the terminating location by constructing their own private networks.[12] By requiring that access to the local exchange be non-discriminatory and unbundled, the *MFJ* impelled the FCC to design a new system of pricing and cost recovery (Vietor 1989, 71).

Following its approval of the ENFIA tariff in 1978, the FCC initiated a wide-ranging investigation of the entire long distance market structure. The discount arrangement for the access fees paid by OCCs was viewed as temporary. Even with

[9] Greene's plan split 6 of the original 161 and consolidated eight others into four. Final decisions on a handful of other cases was left pending (Temin 1987, p. 296).

[10] *AT&T Plan of Reorganization*, page 12, note 11.

[11] A large end-user of telecommunications services can avoid the local exchange facility by installing a direct connection from its location to the POP of the interexchange carrier of its choice.

[12] This practice is referred to as total bypass.

its superior-quality of access and its dominating market power, AT&T was competing with the OCCs at a sizable cost/price disadvantage. Devising a system of access charges raises similar issues as had arisen in the debates surrounding the separations-and-sttlements process. Both processes require classifying portions of the local exchange facility into interstate or intrastate categories.[13] The proportion of non-traffic sensitive (NTS)[14] exchange-plant costs allocated to the interstate jurisdiction had grown to 26 percent. This was 3.3 times the proportion of long-distance to local usage, and reflected a system of prices that widely diverged from costs. Approximately one-fourth of the fixed costs of the local-exchange networks was recovered from the usage-sensitive, toll charges for long-distance service.

By 1984, AT&T's access costs (both interstate and intrastate) were $15.5 billion, about 63 percent of its long-distance operating costs.

The FCC spent five years in devising an alternate cost-recovery and access pricing mechanism. Among the alternatives that had been considered were the following. At one extreme, all fixed costs of the local networks could be shifted to end-users, on a flat-rate, monthly basis. At the other extreme, they could continue to be paid by long-distance carriers entirely on a usage-basis. The compromise approach was a mix of these two cost-recovery methods, phasing in changing proportions over time. The Access Charge Plan announced by the FCC in December 1982 had four objectives: (1) greater economic efficiency; (2) prevention of uneconomic bypass (defined as bypass that exceeded AT&T's costs); (3) a less discriminatory pricing system, suitable to competition; and (4) preservation of universal service. The plan had three components:

Customer Access Line Charge. Every local subscriber would pay a fixed monthly fee per line (initially 2 dollars for residential customers, and 4 dollars for business customers) that would gradually increase over several years.

Carrier Common Line Charge. Long-distance carriers would continue to pay a variable, per-minute-of-use access fee, which would gradually be phased out, as the customer charge was phased in, until 1990, when they would pay only for traffic-sensitive costs. The discount provided other common carriers under ENFIA would be reduced to 35 percent initially, and then phased out over 30 months as they received equal access.

Universal Service Fund. To assist local phone companies with unusually high fixed cost, the plan would create a fund to which long-distance carriers contributed on a usage basis.

The FCC's Access Charge Plan sparked a major political battle, involving the telephone companies, consumer groups, state regulators, Congress, and Judge Greene. Representative Timothy Wirth, the chairman of Communications Subcommittee, and Senator John Dingell, chariman of the Senate Commerce Committee, led the Congressional battles to try to block it. State regulators believing that the FCC plan

[13]Consequently, both separations procedures and access charges are subject to both federal (FCC) and state (public utility commissions) regulation. State commissions regulate both local exchange carriers (the BOCs and independents) as well as the interLATA, intrastate traffic of the interexchange carriers (AT&T, MCI, etc.).

[14]NTS costs are that portion of a the total costs of a local exchange facilty that are fixed, i.e., that do not vary with the amount of usage. NTS costs refer to local exchange carriers investments in the following categories: customer premise equipment; the wiring inside a customers' residence (or office); the lines connecting the customers building to the telephone companies' central office; and the portion of local dial switching equipment that could be deemed to be independent of usage.

interfered with their prerogratives in local pricing, opposed the plan primarily on jurisdictional grounds. Small business groups and consumer advocates argued that the plan threatened universal service. MCI and other OCCs argued that the plan would be financially devastating to them. On the other side of the fence, only the FCC, AT&T, the BOCs and large corporate users supported the plan in its original form. Facing the likeliness of new legislation and the political heat of a letter co-signed by thirty senators pressing for reconsideration and delay, the FCC Chairman, Mark Fowler, made major modifications to the plan. He postponed the customer charge until mid-1985, agreed to put an upper limit of $4 to the residential customer access line charge, and reinstated the access discount for non-premium access for AT&T's competitors to 55 percent. The first phase of the residential line charge was implemented in mid-1985 at $1 per month, which rose to $2 in 1986 (Vietor 1989, 75).

2.5.6 Equal Access

The AT&T/BOC divestiture triggered far-reaching changes to the structure and operation of the nationwide public switched telecommunications network. One of the most significant changes is a requirement that all of the BOCs must, over a specified period of time, provide Equal Access to and from their defined LATAs for all Interexchange Carriers (ICs), including International Carriers (INCs). Equal Access provides parity to all carriers and users of interexchange services in the type, quality, and price of access to those services. The new switching system features developed for the BOCs to permit Equal Access are described in a number of Bellcore documents.[15]

The BOCs were required to complete their Equal Access conversion programs by September 1 1986 for all Stored Program Control (SPC) switches having over 10,000 network access lines, upon the receipt of a bona fide request from one or more ICs. In 1984, GTE Corporation entered into an agreement with the Department of Justice for the provision of Equal Access in its service areas. The GTE/DOJ Consent Decree was a key element in GTE's acquisition of Southern Pacific Communication Company (SPRINT) and Southern Pacific Satellite Company (Spacenet).

Other LECs became subject to FCC requirments for Equal Access according to an FCC ruling.[16] The ruling provided that end offices equipped with SPC switches had to offer exchange access services equal in type and quality to that offered to AT&T within threee years of the receipt of a reasonable request. In the absense of a request, end offices were ordered to be converted as soon as practicable. The LEC schedule of implementation was to reflect its capital constraints and the market and other business conditions in the area served by the end office. End offices equipped with electromechanical switches were also to be converted to Equal Access as soon as praticable.

Some Technical Aspects of Equal Access

Before concluding this section, because of the centrality of Equal Access to this dissertation, a number of additional details of a somewhat technical nature will be presented.

[15] LATA Switching System Generic Requirements, Feature Specification Document No. 20-24-0000; "Compatibility Information for Feature Group D Switched Access Service", Technical Reference TR-NPL-000258.

[16] *In The Matter of MTS and WATS Market Structure, Phase III.* CC Docket No. 78-72, Phase III, FCC 85-98 released March 19 1985.

Equal Access requires provision of parity or equivalence in the following characteristics (Network Planning Subcommittee 1986, p. 7):

- Network interface arrangements
- Customer dialing plans
- Signaling protocols
- Transmission quality
- Grade of service and blocking probability
- Access charges

As previously mentioned, an interexchange carrier may establish one or more locations within a LATA, known as Points of Presence (POPs) where they interface with a LEC. Access to and from a POP can be either directly to a LEC end-office or to an access tandem, which is a switch for concentrating and distributing traffic. There are four basic options for providing traffic to or from a given end-office:

1. Route all traffic between the end-office and the POP(s) over one or more direct trunk groups.
2. Route all traffic via the Access Tandem, using one or more trunk groups between the Access Tandem and the POP(s).
3. Establish high-usage direct trunks and route overflow via the access tandem.
4. Combinations of the first three.

Routing via an Access Tandem can be more efficient than several smaller trunk groups from each end-office to the POP (Network Planning Subcommittee 1986, 8).

Under Equal Access, a customer has the option of dialing a carrier access code to designate the IC or INC via which a particular call is to be transported. This access code is of the form 10XXX, where the digits XXX uniquely designate a particular IC or INC. The XXX codes, known as Carrier Identification Codes are assigned by Bellcore, which is the administrator of the North American Numbering Plan. The same carrier may be assigned and use different codes for its different services (Network Planning Subcommittee 1986, 9).

A LEC customer may "presubscribe" to a predesignated or primary interexchange carrier (PIC), in which case originated calls are routed to the designated carrier without having to dial the 10XXX access code. Under FCC rules, customers select their PIC via a ballot provided by the LEC. New and existing customers who do not presubscribe to a PIC are randomly allocated to ICs in the same proportion as customers who did make the selection. A presubscribed customer may override the PIC designation by dialing a 10XXX access code. When a call is placed, using the Automated Number Identification (ANI) protocol, the customers telephone number is used to access the customer's PIC assignment from a database containing this information (Network Planning Subcommittee 1986, 9).

The cost of equipping a stored program control (SPC) switch for Equal Access can be significant. There are right-to-use software fees or similar feature pricing from the manufacturer for Equal Access capability and additional memory and/or other hardware requirements. The cost of conversion to end-office Equal Access capability is a serious financial consideration for many smaller LECs. It is possible, however, to replace several switches with new digital switching technology that permits placing a base or host unit at one location with subtending remote units at the other replacement locations. In this manner, the total start-up cost of a cluster of end-offices is substantially lower than for one-for-one replacements. Such an arrangement also provides trunking efficiences since Equal Access traffic to and from remote units is concentrated through the base unit (Network Planning Subcommittee 1986, 24).

"Virtual Access Tandems" are arrangements whereby a manufacturer modifies an Access Tandem having SPC technology to provide Equal Access capabililties on behalf of end offices without SPC technology that subtend the Access Tandem. The Access Tandem emulates the Equal Access function of the end-office. Another alternative for small LECs is to install small microprocessor controlled systems at the end office or Access Tandem as an adjunct to a non-SPC switch. The adjunct performs a role much the same as a virtual Access Tandem.

Divestiture and Regional Development Strategies

The Divestiture agreement created a system in which the main branches of the telecommunications services industry—LECs and IECs—have opposing interests and presumably counter strategies regarding the spatial form of regional economic development. *Ceteris paribus*, an agglomerative form of economic development would seem to be more favorable to the LECs in that it would stimulate intra-LATA traffic, whereas a decentralized geographical pattern of production and cross LATA patterns of commuting are more conducive to higher rates of growth of inter-LATA telecommunications flows.

Chapter 3

Technological Change in Telecommunications Switching

Telecommunications networks are made up three basic components. First, at the ends of the network, are the equipment that initiate or receive communiciations such as telephones, fax machines, or modems connected to computers. A second building block is the transmission system through which telecommunications messages are transported. A growing proportion of these communications flows are being transmitted digitally, i.e., as streams of binary digits, rather than as continuous modulated waves (analog transmission). Transmission media include open-wire lines supported by telephone poles, paired wire cables, coaxial cables, land-based microwave radio relay using transmitting and receiving antennas, , satellite circuits, and fiber optic cables. The final component are the switches that route communications traffic from local distribution systems to regional, national, or international channels, and then back again to the terminating local distribution system.

There are two broad categories of switching systems required in national telecommunications networks. *Local* switches are used to connect local calls or to connect lines to trunks[1] for interoffice calls. Switches used to connect trunks to other trunks for long distance calling are called *tandem* switches. This chapter focuses on the technological evolution of local switching systems, since Equal Access is implemented through local switches. Technological change in switching equipment has entailed cost reductions and the expanision of network capabilities and improvement of customer service and features.

In a telecommunications network, the switching function permits interconnection of large numbers of users in an efficient manner. Switching systems have two essential parts: the switching network and the control mechanism. The former consists of the individual switching devices used to connect the communication paths. The latter provides the intelligence to operate the appropriate switching devices at the required time. Control is the technique by which a switching system interprets and responds to signals and directs the switching network. The control function has evolved from the use of relays and other electromechanical devices to the current system of "Stored-Program Control", whereby new features can be introduced through changes in software rather than changes in hardware. The transfer of such information as dialing and ringing through the switching system is called *signaling*.

Modern switching equipment performs a number of auxilary functions such as: network management, which enables rerouting of traffic to avoid network congestion; traffic measurement, the recording of the traffic loads being carried by the various components of the switching system; billing, the recording of the call level detail

[1] A trunk is the telecommunications industry term for a communication channel between two switching systems. A number of trunks that can be used interchangeably between two switching systems is called a trunk group.

need to correctly charge customers for service; and such maintenance functions as automatically detecting and isolating malfunctioning equipment.

Manufacturers of switching systems typically offer a number of alternative models depending on the required capacity for an end office. The capacity requirements of a switching system depend on three parameters: the number of call attempts that the system can process per hour; the total traffic load that can flow through the switch; and the number of telephone lines or number of trunks which can be physically connected to the switch.

There is considerable variabilty in traffic load[2] for different times of day, different days of the week, and different seasons of the year. Switching systems are designed to handle the peak demand (the peak hour of the peak season). Since the time-of-day usage patterns of businesses are very different than residential patterns, the mix of business and residential customers in the geographical area served by a local switch affects the timing of the peak demand.

Switching systems are replaced either to increase the capacity of the switch in the context of growing demand or to replace older technologies with more modern systems. Modernization tends to lower operating and maintenance costs as well as offering new or enhanced service features.

3.1 Electromechanical Switching Systems

In 1889, A.B. Strowger invented the first automatic switching system. The Stowger system, also referred to as the **step-by-step** system, did not begin to be extensively deployed in the Bell System until 1919 (AT&T Bell Laboratories 1983, 398). These systems function in a *step-by-step* manner in both the way the switching network path is established, as well as in the way in which each of the switches in the path operates. Each of the dial pulses generated by the initiating customers telephone progressively controled the functional sequence. This kind of direct-control system required considerable movement of multiple contact arms to establish a switching path through a central office. In 1960, these kinds of switches accounted for approximately 50% of the installed capacity. These systems were most cost effective in smaller cites. The progressive control nature of the step-by-step system precludes service functions such as touch-tone dialing and alternated routing, unless auxiliary equipment is added at the central office.

Another technology, know as the **panel** system, first placed in service in 1921 (AT&T Bell Laboratories 1983, 399), was more oriented toward large city use. The panel system incorporated an early form of common control. With this added feature, complex electrical functions needed only for brief periods during a telephone call were not held out of service for the duration of a call, but rather were used in rapid sequence in order to service many calls. Panel switches' share of the market reached their peak in the early 1940's.

Another metropolitan oriented system know as **crossbar** began to be introduced in the late 1930s. In a crossbar switch, the mechanical motion needed to establish an electrical connection is reduced significantly. Two arms, each rotating through small angles, make connections at any position in a coordinate array and thereby considerably speed up the operation of a switching network. The name *crossbar* refers

[2]Load on a communications network is measured in units called erlangs (named after the Swedish traffic theorist A.K. Erlang), defined as average call arrivals per hour times average call duration (measured in proportions of an hour). In the U.S., load is more commonly expressed in hundreds of call-seconds (CCS) per hour, with 1 erlang equal to 36 CCS.

to the use of horizontal and vertical bars to select the contacts. Crossbar switches permited several calls to share the same switch at the same time. The crossbar technology completed the switching function much more rapidly than the step-by-step approach. Bell Laboratories designed the No. 1 Crossbar model for large city use. It first went into service in 1938 in an end-office in Brooklyn. After World War II, another Bell Labs design called the No. 5 Crossbar System, adapted to the needs of small cities and suburbs, was introduced. New No. 5 Crossbar systems were being installed up until 1977 (AT&T Bell Laboratories 1983, 399).

3.2 Electronic Switching Systems

Electronic Switching Systems (ESS), developed by Bell Laboratories in the 1950s, were made possible by the invention of the transistor in 1947. The first commercial use of an electonic switching system in the Bell System was the *1ESS* model introduced in Succasunna, New Jersey in 1965. *1ESS* switching equipment was oriented toward serving between 10,000 and 65,000 customer lines. The *2ESS* was introduced in 1970 to serve smaller end offices (2,000 to 10,000 lines). Another model, the *3ESS* was introduced in 1976 to serve rural end offices serving less than 4,500 lines. A new generation of processor, using time-multiplexed digital control, greatly extended the capacity of electronic switches. The new processor was designed so that it could be retrofitted into existing switches.

ESS makes use of glass-enclosed reeds. These are small strips of metal which, in their protected environment, operate reliably at high speed upon the application of magnetic fields. In ESS, the concept of common control advanced to the idea of Stored Program Control (SPC). The logical steps entailed in establishing telephone connections are determined according to software stored in the equipment. In contrast, pre-SPC systems designed the logic into electromechanical or electronic circuits. In ESS systems, new services can often be introduced by making programming changes to the SPC software, rather than by physically re-wiring circuits. With SPC, the requirements for a central office are divorced from the office's specific, physical items of equipment. The evolution of semiconductor technology has reduced the size, energy consumption, and cost of switching element components as well as increasing the speed, durability and reliability of the equipment.

So called Remote Switching Systems (RSS) were introduced to serve rural areas in which end offices provided service to under 2,000 lines. These small office markets generally did not justify the cost the existing ESS models. Remote switching was based on the idea of sharing the processing capabilities of a nearby electronic switching systems and using a microprocessor for control functions directed by the host central processor. The host controls the remote equipment over a pair of dedicated data links. Customer lines are terminated at the RSS but processed by the host system. RSS equipment can independently serve intraoffice calls, making it suitable for rural markets, in which it is estimated that as many as 65% of calls are for intraoffice communications (AT&T Bell Laboratories 1983, 234).

3.2.1 Digital Switching

Digital switches are electronic switches that make use of *time-division switching* in which different communications messages are allocated to different time-slots, rather than physically discrete paths (*space-division switching*). One of the benefits of a digital switch is the direct combatibility with digital transmissions, eliminating the need for digital to analog conversion. The development of digital switching, however, has proceeded at a slower rate of progress than achieved for digital transmission. Another benefit of digital exchange systems, in part due to their module design, is their greater flexibility for incorporating improvements and new features embodied in software building blocks.

TABLE 3.1: Central Office Switching Expenses (end-of-year 1989)

	Total Expense	Labor Expense	Equipment Type Shares	Labor Expense Share of Total Expense
	(thousands of dollars)		(percent)	
RBOCs				
Electro-Mechanical	243,330	198,763	11.3	81.7
Analog Electronic	929,415	689,117	43.2	74.1
Digital Electronic	979,324	432,664	45.5	44.2
Total	2,152,069	1,320,544	100.0	61.4
Other Reporting LECs				
Electro-Mechanical	106,779	75,126	16.9	70.4
Analog Electronic	94,845	64,976	15.0	68.5
Digital Electronic	430,356	230,116	68.1	53.5
Total	631,980	370,218	100.0	58.6
All Reporting LECs				
Electro-Mechanical	350,109	273,889	12.6	78.2
Analog Electronic	1,024,260	754,093	36.8	73.6
Digital Electronic	1,409,680	662,780	50.6	47.0
Total	2,784,049	1,690,762	100.0	60.7

Source:
U.S. Federal Communications Commission)
Statistics of Communications Common Carriers
Washington, D.C., 1990, pp. 28-30

3.3 Changes in the Labor Process

Table 3.1 shows the substantial drops in the labor cost component of total switching expenses corresponding to different vintages of switching equipment.

A group of researchers in England undertook a detailed case study of the impact on the labor process in telecommunications switching stations of British Telecom's network modernization strategy (Clark, et al. 1988). Studies of this kind are particularly useful for getting beyond the abstractions typical of theoretical models of technological change. As the study of Clark and his associates is one of the few to have investigated local switching technology, it will be reviewed in detail.

The study concerned the introduction of a medium-sized semi-electronic switch called the TXE4 as a replacement for Strowger electro-mechanical exchanges. Eight separate exchanges in different phases of conversion and serving somewhat different kinds of service areas were the subjects of the approximately year-long research. The research methods included observation of work activities, questionnaires, self-reporting diaries, and inverviews for a sample of 51 maintenance technicians and supervisors. The study was intended to shed light on how corporate strategies were attenuated at the operations level of management.

The British Telecom experience is in some measure analogous to the transformation of the "corporate culture" of the post-divestiture U.S. telecommunication industry, characterisized by a public-service ethos being replaced by a market-driven commercial orientation. In the British case, the events that brought about the shifts were the splitting of the Post Office into separate and independent postal and telecommunications public corporations in 1981 and the privatisation of British Telecom in 1984. The decision to adopt TXE4, however, was made in 1973, well before these events.

The TXE4 offered the promise of dramatic improvements in quality of customer service, but the decisive factor in the choice of the new technology is deemed to have been the considerable cost savings from substantially reduced maintenance.

The engineering technicians that worked at the switching stations under study were members of the Post Office Engineering Union (POEU), whose total membership of around 130,000 in 1983 made it the largest union in the country. Supervisors and middle management staff were represented by the Society of Telecom Executives, who seem to have been content to view modernization as a managerial prerogative and not a legitimate subject for collective bargaining (Clark, et al. 1988, 207). The POEU tended to adopt a favorable view toward technological change, believing that the expansion of the telecommunications market would offset any lower labor requirements of new technologies. In 1978, the POEU negotiated a national agreement with British Telecom concerning the staffing level, job security, pay and grading issues connected with TXE4 modernization. The agreement was reached in a context in which: reducing the labor costs associated with exchange maintenance was a primary motive for modernization; the new commercial orientation was putting more emphasis on rationizing staffing levels; and local management was seeking to be less constrained by national standards (Clark, et al. 1988, 71).

The researchers concluded that the relationship between technological change and work tasks and skills associated with the introduction of TXE4 was complex and multidimensional. There are two main types of maintenance tasks of technicians in telephone exchanges. One involves the maintenance work on the switching equipment itself, and the other is concerned with the peripheral equipment. For the Strowger technology which is composed of thousands of moving mechanical parts, the maintence activites included such tasks as testing, cleaning, oiling, realigning, and, when necessary, replacing any worn-out parts or electrical contacts. Routine testing activities are meant to identify fault conditions. Once identified, fault conditions need to be located, diagnosed, and repaired. For Strowger exchange systems, fault conditions could usually be isolated without affecting other customers' service.

With the massive reduction in the number of moving parts of a TXE4 exchange relative to a Strowger exchange and the in-general greater reliability of electronic components, such routine activities as cleaning, lubricating and adjusting were a mucher smaller aspect of maintenance work. Although the TXE4 provides technicians with much more information than Strowger equipment on the existence of fault conditions, diagnosing the cause of the fault tends to be more complex. In addition, the greater reliability of the TXE4 exchanges meant that faults would occur only infrequently and tend to be more unusual. In contrast, the regular and predictable faults of the Strowger equipment required less refined diagnostic skills. On the other hand, once faulty TXE4 equipment was located, its repair was rather straightfoward (Clark, et al. 1988, 113).

The maintenance of TXE4 exchanges requires such skills as mental diagnostic and interpretive abilities combined with a thorough understanding of the system. The Strowger exchanges in contrast require manual dexterity and an emphasis on refined aural and visual abilities. The transition between the two systems involves "de-skilling" of certain tasks and "up-skilling" in relation to other tasks. The introduction of the TXE4 led to the emergence of a more unaccommodating division of labor between senior and junior technicians. For the exchanges that were studied it was found that because junior technicians were excluded from re-training programs, the traditional connection between skill acquistion and a clear progression through the occupational structure was broken. It was found that there was a tendency toward polarisation of the workforce into distinct and segmented occupational groups than had been the case in Strowger exchanges.

In the late 1980s, British Telecom began to introduce an all-electronic digital exchange system that was called System X. The new units imply a radical break with previous technologies. System X makes use of centralized control of maintenance operations, thereby involving a redefinition of the concept of the workplace. The monitoring of exchange performance no longer needs to be a task performed at the same physical location where the switching equipment is housed. That is, data on all aspects of an exchange's performance can be routed to a remote computer center. Another aspect of the digital equipment maintenance is that since faults are likely to be extremely infrequent, in order to retain their skills, simulated faulting exercises will become one of the primary activities of maintenance technicians.

Zuboff's well-known book *In the Age of the Smart Machine* contains a few pages of description of centralized control of switching centers in the U.S. context (Zuboff 1988, 327–337). She describes some of the problems of remote supervision, in which the switching system technicians are dispersed to the various sites comprising the territory of the centralized control center where they usually work in isolation. In this new context, supervision is accomplished without direct observation. Information on switching unit faults are received at the central control unit, transformed into work requests, which are in turn made into work load assignments for each technician. The workers are then required to remotely enter information on their completed tasks, enabling real-time monitoring of their work behavior. Zuboff describes how efficiency ratings are automatically calculated by comparing the amount of time required to complete a job with the norm for that task.

TABLE 3.2: Market Shares of Suppliers of Central Office Equipment

Company	1989 Shipments[1]	Market Share
AT&T	6,100	47.1%
Northern Telecom	4,670	36.0%
AG Communications	1,070	8.3%
Stromberg-Carlson	572	4.4%
Siemens	340	2.6%
NEC	165	1.3%
Alcatel	25	0.2%
Ericson	18	0.1%
TOTAL	12,960	100.0%

1. Thousands of lines.
Source:
Dataquest,*Market Statistics-Central Office Switching Equipment*
February 1991, Table 3, p.4

3.4 The Manufacturers of Central-Office Switching Equipment

Table 3.2 shows the relative penetration of the U.S. market in central office switching equipment as of 1989.[3] One of the ramifications of the divestiture agreement was the opening of this market to more intense foreign competition. Actually, AT&T's dominant position in the U.S. market began to erode as early as 1980. Northern Telecom, which was able to begin offering digital switches before AT&T, won 75% of the pre-divestiture sales of digital switches to the Bell Operating Companies (Huber,1987, 14.5).

Throughout the world, there has historically been a vertical integration between telecommunications equipment suppliers and telecommunications services companies. In the current market, even where common ownership relationships have been servered, the national equipment manufacturers have tended to be the preferred vendors to the national telecommunications services providers.[4] One of the reasons for the persistence of preferential buying arrangements, even in a regulatory context in which LECs have been instructed to buy the best possible equipment at the lowest possible price, is the value of preferrential or early access to information concerning network plans, historical operating experiences, and future technical specifications (Huber 1987, 14.13).

The research and development costs for modern digital switches are enormous, reaching as much as a billion dollars. Economies of scale, particularly in R&D, are tending to lead to consolidations in the world market (Huber 1987, 14.8). Since the technical specifications tend to vary between countries, a significant portion of R&D

[3]The figure measures market shares by shipments of lines. Other measures such as installed base in terms of lines or sales revenues was not available on as complete a basis.

[4]For instance, AT&T remains the preferred vendor to the RBOCs. The manufacturing arm of GTE has tended to be the principal supplier of the GTE LECs. At least part of the impetus for the GTE companies to diversify their sources of supply has come from regulatory pressures from state public utility commissions demanding adoption of competitive bidding procedures or from antitrust suits brought by potential competitors. Bell Canada subsidizes the research and development expenses of Northern Telecom, which remains its principal supplier. Similar relationships exist between Deutsche Bundepost and Siemens, British Telecom with Plessey/Stromberg-Carlson, NTT with NEC (in Japan), Televerket with Ericsson (in Sweden), and the French telecomunications system with Alcatel. In the Swedish case, Televerket, a government agency, was both a telecommunications services provider and manufacturer. Ericsson, therefore, from very early in its corporate history, unlike most of the other international manufactures, had to rely to a considerable extent on the international market.

expense is required to adapt generic designs to peculiarities of each national market. It is estimated that approximately half of the total cost for bringing a digital central-office switch to market is for the basic and applied research, including generic product definition, design, and the development of detailed product specifications. Approximately one third of the total is for development, implying a relatively small amount for the final manufacturing expense. It has been suggested that if the RBOCs were released from the probition on establishing affiliates for the manufacturing of their own central-office equipment needs, that the size of their potential captive market would be insufficient to sustain entry into this market with non-competitive products (Huber 1987, p. 14.14). In the current world market, a single RBOC market or a single national market in Europe, seems to be an insufficient scale of operations to be able to remain competitive.

Chapter 4

Theoretical Underpinnings and Empirical Antecedents

The hypotheses that I will test in the proposed dissertation were formulated from study of theoretical and empirical research in two areas of economic analysis: (1) innovation diffusion (Bearse 1976; Brown 1981; David and Bunn 1988; Rose and Joskow, 1988); (2) uneven regional development and restructuring (Castells 1985; Castells 1988; Gillespie and Williams 1988; Gottdiener 1985; Gregory and Urry 1985; Harvey 1988)

4.1 Theories and Empirical Studies of Innovation Diffusion

Technological diffusion is the term used to describe the spread of new technologies over time. In some treatments the spatial aspects of the diffusion are explicitly incorporated and sometimes are the central focus. The early literature mainly concerned the demand for new products and processes. More modern treatments bring the supply of innovations into the picture. In some treatments diffusion refers to the proportion of firms (or households) that have chosen the new technology at various points in time. In other approaches, the diffusion process is analyzed in terms of the proportion of total output that is produced using the new technology. Theoretical and empirical models also differ with regard to their level of aggregation addressed, both with regard to the innovation commodity (i.e., a specific product or a group of similar commodities that can be meaningfully aggregated) and the range of adopters (sub-units of a single firm, firms in an industry in a single country, firms in an industry on a world-wide basis, firms across industrial sectors, economy-wide, worldwide, etc.).

A common point-of-departure is examination of the time path of diffusion of an innovation. The majority of empirical studies have found that the plot of a diffusion path is a sigmoid (or S-shaped) curve, in which the rate of diffusion first increases and then decreases after the inflection point. Many of the early studies attempted to fit logistic growth curves to empirical data. A logistic equation is justified theoretically for simple epidemic models in which the rate of diffusion is hypothesized to be proportional to the fraction of adopters and the fraction of potential adopters left. One of the advantages of the logistic curve is that its parameters can be estimated by a linear equation.

One of the better known early empirical studies based on the logistic curve is Griliches's study of the spread of the use of hybrid corn in 31 different US states. His diffusion variable is the proportion of corn acreage in each state planted with hybrid seeds. Griliches noted that the diffusion pattern in the corn belt states was notably different from the other states; hydrids became available in the corn belt in the early 1930s but only began to appear in the south in the 1940s. At the time of his study, in many of the states the diffusion process was far from complete. He needed therefore to estimate ceiling values for each state, both in order to be able to estimate the logistic parameters, and because the ceiling value was considered to be an important indicator in its own right. Griliches then went on to explain the parmeters differences obtained for the different states by interstate differences in the expected profitability.[1]

As a reflection of the importance of Griliches early work, 23 years after his original article, *Econometrica* published an updating and extension of his work prepared by Dixon. Dixon re-estimated Griliches' logistic equations with sufficient additional data points so that the fraction of acreage planted with hybrid seed reached 100 percent in every state. He found that a Gompertz curve (which allows for asymmetry) provided a better fit than a logistic curve (which imposes symmetry) for 21 out of the 31 states. Dixon then went on to re-evaluate Griliches' profitability analysis using updated versions of the logistic parameters and the Gompertz parameters as alternative versions of the dependent variable. He concluded that the original finding of a close association between the variability in the rates of diffusion across states with yield per acre and acres per farm remained robust when more recent data and improved estimating techniques were employed.

Another well known innovation diffusion study based on first fitting logistic curves and then developing a model to explain the rate of diffusion parameter is that of Mansfield (Mansfield 1971). In a 1961 *Econometrica* article, Mansfield analyzed twelve innovations in four industries.[2] Mansfield argued that the diffusion rate, which he called the rate of imitation–the speed with which other firms in an industry follow an innovator–would be positively related to the profitability of installing the innovation relative to other investments, and be negatively related to the relative size of the required investment. He also hypothesized that the innovation rate would: be lower for equipment with long service lives; be higher for rapidly growing firms (in which case it is more likely that the innovation can be for expansion investment rather than replacement investment); and vary according to the phase of the business cycle (be higher in the expansion phase and lower in the contraction phase. For his data on the twelve innovations, he found the found the profitability and investment size variables to be highly significant, but the latter four effects to be statistically insignificant.

[1]The rate of acceptance parameter (the slope of the time trend of the state-specific logistic equations) was used as the dependent variable and the pre-hybrid yield per acre and average corn acres per farms were used as his explanatory variables. He related his results to early studies by sociologists that had explained the decision to adopt hybrid corn on the basis of such variables as personality, education, economic status, and social environment. He argued that he was modeling at an aggregation level in which these variables either cancel each other out or do not vary sufficiently from area to area (Griliches 1971, 226).

[2]The innovations considered were:

Bituminous coal industry. The shuttle car, the trackless mobile loader, and the continuous mining machine.

Iron and Steel industry. The by-product coke oven, the continuous wide strip mill, and the continuous annealing line for tin plate.

Brewing industry. The pallet-loading machine, tin containers, and high-speed bottle fillers.

Railroad industry. The diesel locomotive, centralized traffic control, and car retarders.

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4.2 Duration Models

The econometric portion of this dissertation was greatly influenced by Rose and Joskow's (1988) study of the diffusion of steam-electric generating technologies in the U.S. electric utility industry. Rose and Joskow analyzed the diffusion of two alternative technologies[3] using data on 144 utilities that built steam generating plants between 1950 and 1980.

One of the contributions of Rose and Joskow's research was their distinction between a firm's innovativeness–the explicit decision to employ a new technology–and the early use of a technology that is due to the firm's opportunities or more frequent need to replace old capacity or add new capacity. A large firm having the same growth rate as a small firm will tend to need to add new capacity at a faster rate. Such an effect, they point out, should not be considered to reflect a greater propensity to adopt new technologies, but rather as a difference in opportunities.

The theoretical and empirical literature on technology diffusion has generally considered the following factors to affect the pattern of adoption:

- The expected cost savings. In the Rose and Joskow study interfirm and intertemporal differences in fuel costs were expected to contribute to significant variation in the relative appeal of the new technologies.

- Uncertainty over the distribution of expected savings. Greater uncertainty about potential savings is expected to result in a slower adoption rate.

- Firm size. Rose and Joskow hypothesized that firm size might infulence innovativeness through one or more of the following channels:

  - Because larger firms are more likely to have internal engineering, design, and maintenance staffs they would tend to have greater interest and capability for early adoption of new technologies.
  - Larger firms, having a larger capital stock, may be more likely to be less risk adverse, if a few "bad" investment decisions have a negligible impact on overall profitability.
  - Larger firms may be better positioned to achieve economies from the abiltiy to operate more plants using a given technology.

- Ownership structure. The Rose and Joskow study included private investor-owned utilities, municipal and other government owned utilities, and cooperatives. Although the private utilities were subject to rate of return regulation, regulatory lag would provide incentives to adopt cost-saving technologies. Furthermore, since new generating technologies tend to be more capital-intensive than older generating units, there is an additional incentive for early replacement of old units with new ones. Municipal utilities and cooperatives tend to spend proportionally less on research and development.

- Time. Rose and Joskow investigated the impact of using functional forms that did not impose monotonic diffusion patterns. They hypothesized that the adoption probabilites should initially increase and then decline.

[3]Conventional high pressure units (2400 pounds per square inch (psi)), and very high pressure supercritical units (above 3206 psi).

4.3 Innovation and Company Strategies

This thesis draws upon the newer literature that has sought to make the analysis of technological change more realistic by incorporating theoretical treatments of firm stategies. The assumption of perfect knowledge obviates the need for an analysis of strategy in the orthodox theory of the firm. The need for a theory of strategy only arises in the context of uncertainty.

The analysis of strategy often takes as a point-of-departure a distinction between the internal and external selection environment of the firm (Coombs, et al. 1992, 9). The internal environment of the firm–its communications structures and mechanisms for making decisions–determines the firm's response to options emanating from the external environment.

There are a number of different conceptions of strategy that have been developed. Porter's approach consists in relating a company to its competitive environment. This environment is driven by the extent of market entry, the threat of substitution, the bargaining power of buyers and sellers, and the degree of rivarly among the competitors. Another perspective defines strategy in relation to either the exploitation of the firm's existing resources and capabilities or the creation of new capabilities. The dynamic capabilities approach stresses learning processes.

The term technological trajectory has been introduced to refer to the phenomenon of persistent patterns of change experienced historically such as: increasing mechanization in manual operations; increasing speed of computations in computers; and continuing advances in the miniaturization of microelectronic components. MacKenzie (1992) argues that technological trajectories tend to be self-fulfilling prophecies in that persistent patterns of technological change are in large measure due to the belief that they will be persistent. Consensual estimates of the direction and rate of technological advance are drawn upon by designers to aid their judgment regarding what their new designs must achieve in order to be competitive. He argues that because of risk and cost, expectations concerning technological futures may serve to limit the ambitiousness of new designs.

4.3.1 Innovation of network technologies

In a recent article, David and Bunn (1988) have examined some of the interesting special features of innovation in a network-based industry. In their study, which deals with the history of electric power, they discuss two issues of central importance to this dissertation. Firstly, they highlight the key features of *network technologies* . Namely, that these technological systems are characterized by: increasing returns to scale; users linked in a network; the existence of positive externalities from use of the network; and lastly, the need to coordinate the operation of the many constituent parts of the system. Secondly, they make use of the notion of a *'gateway innovation'*, by which they mean the introduction of an innovation that permits the technical linkage of system components that, in its absense, would remain disconnected. They describe how the seemingly small event of the introduction of the rotary converter led, in a short span of time, to the end of the rivalry between alternating current and direct current power systems. In an analogous manner, the incorporation into switching systems of the software providing an Equal Access capability, enabled the rapid intensification of competition among inter-exchange carriers.

4.3.2 Spatially oriented innovation diffusion

At least since the work of the Swedish geographer, Torsten Hagerstrand[4], spatially oriented analyses of diffusion processes have repeatedly identified the following three empirical regularities: (1) plots of the cumulative level of adoption approximate an *S*-shape; (2) a hierarchy effect, in which diffusion proceeds from larger to smaller urban centers; and (3) a neighborhood or contagion effect, such that diffusion is expected to progress outward from a center, affecting nearby areas before locations further away from the originating point. In a later section I will describe ways that I propose to test for these effects in the context of the Equal Access process. Here, I will draw attention to a number of alternative paradigms from which to theorize about such processes. I will also highlight similarities and contrasts of my proposed investigation with other innovation diffusion studies. Brown (1981), whose work is explicitly concerned with spatial aspects of innovation diffusion processes, identified four orientations according to which the diffusion literature can be classified: (1) The *Economic History Perspective*, in which there is a stress on the social and economic preconditions for diffusion, and a focus on the change in the environment into which the innovation is adopted throughout the life of the innovation process; (2) The *Adoption Perspective*, which conceptualizes the unfolding of an innovation across space as principally the result of a learning or communications process; (3) The *Market and Infrastucture Perspective*, which attaches great importance to the establishment of diffusion agencies and the implementation of strategies designed to induce adoption of innovations; and (4) The *Development Perspective*, which emphasizes the relationship between the overall level of development and the diffusion process.

The models introduced in Chapter 5 entail elements of each of these perspectives. Particular emphasis will be given to placing the Equal Access process in its historical context.

4.4 Theories and Analyses of Regional Structure and Transistion

4.4.1 Castells' Theory of the Informational Mode of Development

Castells' (1990) recent book *The Informational City* was a fundamental source in formulating the theoretical underpinnings of this work, particularly with regard to the relationship between what Castells terms the 'Informational Mode of Development' and regional restructuring. As part of his endeavor to place analysis of technological change within the framework of a broader social theory, Castells introduces the concept of mode of development. The mode of development is defined by the fundamental features of technological arrangements governing the *level* of surplus[5] generated by the mode of production[6].

Castells identifies three, increasingly advanced, modes of development: the agrarian, in which surplus is increased by quantitative increases in labor, land and means of production; the industrial mode, in which new or improved energy sources are

[4] see (Brown 1981; Morrill, Gaile, and Thrall, 1988)

[5] The share of the product which exceeds the historically determined needs for the reproduction of labor, means of production, and social institutions.

[6] The rules according to which social structures interact with production processes so as to determine the appropriation and distribution of the surplus. The mode of production refers to social organization, whereas the mode of development refers to the technological infrastructure of the society.

the main element in increasing the surplus; and the informational mode, the main mode of production relevant to Castells' book. In the informational mode of development, improvements in the quality of knowledge generates higher productivity. Castells argues that the performance principle, or structurally determined goal of informationalism[7] is the pursuit and accumulation of knowledge.

Castells associates the onset of the information mode of development with the new technological paradigm constituted by scientific and technological innovations since the 1960s in microelectronics, telecommunications and genetic engineering. Two fundamental features characterize the new technological paradigm. The primary distinguishing feature is the focus of the core technologies on information processing. Information is both the 'raw material' and the output of the information technologies. The second major characteristic of the new technological paradigm is that their primary impact is on transformation of processes rather than on products. Castells recognizes that this characteristic is not unique to the information mode of development. The impact of the steam engine and electricity were similar in this regard.

Castells traces the origins of the new centrality of information processing to the following social developments in the spheres of production, consumption and state activity: (1) the information flows linked to the ascendancy of the large corporation as the dominant organizational structure for production and management, with its attendant needs to coordinate hierarchical and dispersed operations; (2) the growing knowledge intensity of production processes; (3) the information gathering systems utilized to stimulate consumption by means of methodically targeted marketing; and (4) the network of information flows controlled and manipulated by bureaucratic state apparatuses.

New information technologies affect profit rates by improving the power of capital in relation to labor. Advanced telecommunications and flexible manufacturing systems enable decentralization and spatial dispersion of different corporate subunits. Threats to automate, relocate, or increase utilization of temporary or part-time workers are used to extract concessions in wage and benefit negotiations.

4.4.2 Noyelle and Stanback's Classification Schema

Noyelle and Stanback's *The Economic Transformation of American Cities*, published in 1984, is one of the more important and influential empirical studies in regional economics in recent years. Among the issues that they addressed were:

- Development of a typology for examining the hierarchical structure of the U.S. system of cities.
- The nature and extent of agglomeration tendencies.
- The cummulative effects of historical develpment on contemporary metropolitan structures.
- The source and impact of transformational capacities.
- The spatial implications of networks of corporate control and development.
- The role of centrifugal and centripetal forces in the structuring and restructuring of intermetropolitan linkages.

[7]Used synonymously with information mode of development.

Noyelle and Stanback classified the 140 largest U.S. SMSAs into 11 groups by means of a cluster analysis of employment-based standardized location quotients for the following sectors: manufacturing; distributive services; transportation, communications, and utilities; wholesale trade; retail trade; finance, insurance, and real estate; other corporate services; complex of corporated activities; central administartive offices and auxilary establishments; health and education services; and government.

They described their clustering methodology as consisting of the following steps. Using 1976 data, standardized location quotients were calculated for the 11 sectors for each of the 140 SMSAs. The clustering algorithm formed 19 clear-cut clusters based on the similarity of employment structures[8]. The 19 clusters were reduced to 7 groups. The names that Noyelle and Stanback assigned, listed in order of increasing within-cluster maximum Euclidean distance, are:

1. Education-manufacturing
2. Manufacturing
3. Resort-retirement
4. Nodal
5. Government-military
6. Mining-industrial
7. Functional nodal

For some of their analysis, further grouping, producing a four-way split of the 140 SMSAs was introduced. The “education-manufacturing” and “government-military” and “functional nodal” groups were considered to be “specialized service centers”. The “manufacturing” and “mining-industrial” groups were combined into a “production centers” category.[9]

4.4.3 Core and Periphery Theories

Much of the social science literature on territorial uneven development utilizes the conceptual categories of core and periphery. Most of this literature is concerned with the analysis of countries’ positions in world systems. There have, however, been efforts in applying the conceptual framework to the analysis of regional differention within countries. Many of the processes of uneven development studied at the level of the world-system also occur within countries and these are not only analogous processes. They are often historically linked with one another. The urban hierarchies which characterize national city systems are another manifestation of regional stratification within countries, as is the urban/rural dimension.

[8] Measured by the magnitude of Euclidean distances between city pairs.

[9] For other discussions further refinement of the 7 groups was introduced. The “nodal” group was disaggregated into 3 subgroups on the basis of population size or the uniqueness of the activities comprising the complex of corporate activities. The “government-military” group was split into “government-education; and “military-industrial” on the basis of the federal civilian and military share of total wages and salaries paid in the SMSAs forming the group.

Terminology and Definitions

Raul Prebish (1949), Johan Galtung (1971), and Samir Amin (1974) used the terms "center" and "periphery". Andre Gunder Frank (1969) preferred the terms "metropole" and "satellites". Chase-Dunn (1989) argued that "core" is preferred to "center" because it suggests an area rather than a point. Similarly, he argued that "periphery" should be thought of as a large category, not just an outside edge.

What have been considered to be the structural features of core areas that distinguish them from peripheral ones? Many authors have claimed or implied that the division of labor between the industrial production of process goods versus the the extractive production of raw materials or agricultural commodities is the key economic dimension. Albert Hirschman's (1980) study which examined the effects of the level of processing of exports and imports on national economic power was an important source for the "level of processing" argument. Galtung reasoned that a national economy which produces mainly highly processed goods will have a higher rate of growth because of more integrated forward and backward linkages within the constellation of economic activities in the national economy. New investment in this context will generate greater spinoffs and multiplier effects. Regional economies in which primarily extractive raw materials or agricultural products are produced are likely to be less internally differentiated, less internally linked, and thus new investments are unlikely to stimulate much local growth.

Wallerstein (1979) defined core activities and peripheral activities as distinct characteristics of nodes on "commodity chains". Commodity chains consisted of tree-shaped interconnections beween processes of production, distribution, and consumption. Wallerstein argued that the nodes or loci of activity along commodity chains can be distinguished in terms of the returns they receive. Core activities receive disproportionately high returns, whereas peripheral activities receive low returns. This distinction is conceived of as dichotomous so that each activity is either core or peripheral. A core area is one in which a relatively high proportion of economic activities are core activities and vice versa for peripheral areas. A "semiperipheral" area is defined as a region containing a relatively equal mix of core and peripheral activities.

Giovanni Arrighi and Jessica Drangel (1986) disagreed with Wallerstein's tendency to define core activity in relation to the capital intensity of production. Both raw material and agricultural production may be carried out as core production if capital intensive technology is combined with skilled, well paid labor. Rather they defined core activity as that economic activity which receives relatively high returns regardless of the substantive nature of the activity. They adopted a definition of core activity derived from Schumpeter's argument that the driving force behind capitalist accumulation is the ability of organizational entrepreneurs to develop new activities which enable tham to capture a large share of the returns to economic activity. This may occur in financial or commercial activities rather than just in the realm of product development and production. Arrighi and Drangel argued that core activity consists in the ability of some firms to capture relatively greater returns by protecting themselves to some extent from the forces of competition. Peripheral activity, on the other hand, is exposed to strong competiton and thus the level of returns is low.

Chase-Dunn defined core activity as the production of relatively capital intensive commodidities which employ relatively skilled, relatively highly paid labor. This is a relational idea because the level of capital intensity which constitutes core production during a specific period is defined as relative to the average level of capital intensity in the world-system as a whole. Since average capital intensity is a rising trend, forms of production which once were core production may become peripheral production at a later time. Capital intensity involves the utilizaton of techniques which facilitate high productivity per labor hour.

In Chase-Dunn's framework, a core area is one in which relatively capital intensive production is concentrated. Although capital intensive production is often in the manufacturing or industrial sector of a national economy, it may also be in the service sector, the agricultural sector or other sectors. Agriculture in core areas is usually also capital intensive relative to agriculture in other zones of the world-system, as is the case for services.

He argued that dichotomization creates the false dilema of where to locate the dividing line. Rather the core/periphery dimension should be viewed as a continuous variable between constellations of economic activities which vary in terms of their average relative levels of capital intensity versus labor intensity.

Amin (1974) and de Janvry (1981) define core capitalism as self-reproducing, relatively integrated, capitalist accumulation, whereas peripheral capitalism is understood as a disarticulated regional economy which is highly dependent on imports from, and exports to, the core. The differential integration of regions and nation states has long been, and remains, an important feature of the core/periphery framework.

Another definition important in core-periphery theory is that of "semi-periphery". In Wallerstein's definition there are not semiperipheral activities as such. Rather there are semiperipheral states which contain a balance of both core and peripheral activities.

Semiperipheral states, containing a balance of both core and peripheral activities, are viewed as being likely to produce contradictory economic and political interests within the boundaries of a single state. Instead of the notion of a mix of core and peripheral activities, the semiperiphery can also be defined in terms of the relative level of capital intensity/labor intensity.

Chase-Dunn argued that a semi-peripherality consisting of a balance of core and peripheral activities will tend to experience political conflict over state policy due to conflicting regional interests. In contrast, a relatively uniform but intermediate level of semiperipheral activities, will be much less likely to experience conflict among different kinds of capitalists.

Empirical Studies Based on Core-Periphery Theories

Arrighi and Drangel found a trimodal distribution of countries based on GNP per capita as a measure of position in the core/periphery hierarchy. Nemeth and Smith (1985) used a network analysis of the level of processing of imports as a measure of the core/periphery structure–revealing a four-tier hierarchy with two distinct semiperipheries. GNP per capita is considered to be an apposite measure for studies of world-system position because it is available for a large number of countries over fairly long time periods. Chase-Dunn argued that is would be preferable to use the amount of product divided by the number of hours worked, because capital intensity is very nearly the same as labor productivity. A proxy for this could be the ratio of GNP to the size of the active work force. David Snyder and Edward Kick (1979) used cluster analysis to determine the structural similarities among groups of countries based on four international interaction matrices. The four matrices they analyzed were the value of trade between countries; military interventions; the exchange of diplomats, and the existence of treaties. Nemeth and Smith used the idea that the level of processing is the key to the core/periphery hierarchy. They combined 5 trade matrices containing different commodity classifications of imports. The 5 trade categories were determined by factor analyzing the trade matrices of 53 two digit commodity classifications. Their structural trade network measure produced a core, two semiperipheries, and a periphery.

Naustdalslid (1977) argued that models of center and periphery that have been applied to the analysis of international systems can also be a useful framework for analyzing interregional differences within one country. Naustdalslid's approach takes Johan Galtungs' model, which explicitly addressed both national and international center-periphery relations, as his point of departure. One of Naustdalslid's objectives was to contribute to bridging the gap between the two generally isolated literatures of international and intranational regional development.

Naustdalslid used the following 8 variables as a basis of analysis of the 19 counties of Norway.

1. Gross regional product per capita.
2. The percentage of the labor force employed in non-primary sectors.
3. Average income per capita.
4. An index of relative consumption defined as the ratio of the county share of national consumption to the county share of national population.
5. An asymmetry index of county sectoral production relative to consumption. The index is constructed from aggregation of 23 economic sectors into two groups: the tertiary sector and industries with a high "degree of processing"; and the primary sector and industries with a low degree of processing.
6. Net interregional population migration.
7. An index of industrial concentration based on the presence within the county of the 500 largest firms in Norway[10].
8. An index of "industrial monoculture" measured by the percentage of total industrial production of a county in sectors other than the two most important for that county.

The first two variables correspond to Naustdalslid's development dimension. The third variable is taken as indicatior of a standard of living dimension. The fourth, fifth and sixth variable constitute a dimension referred to as "vertical interaction relations". These variables are meant to be proxies for the type of commodity exchange between the center and the periphery. The last two variables are meant to operationalize Galtung's dimension "feudal interaction structure", which in Naustdalslid's context is really just meant to be industrial concentration. Galtung's terminolgy derived from the ideas that peripheries are largely limited to dealing directly with their own center, and that interactions among the peripheries of the same center, or with other peripheries or centers is minimal and mediated by each periphery's own center.

Naustdalslid calculated the correlations among the 8 variables. On the basis of the values of the correlation matrix, he claimed that the Norwegian data supported the hypotheses: that the development and standard of living of living dimensions

[10]Using 1972 data. For each firm which is located in a county, the county is assigned a score corresponding to the relative rank of that firm (a score of 500 for the largest firm and 1 for the smallest).

should be highly correlated; and that counties that are centrally placed in the concentration structure should also rank high on the variables measuring vertical interaction relations.

4.4.4 Analyses of the impact of the telecommunications sector on regional development

A number of social scientists have explicitly analysed the bearing of the telecommunications sector on regional development. Among the works closely related to this dissertation are Shawky el-Touchy's recent New School dissertation concerning the impact of telecommunications infrastructure on industrial location in New York state (El Touchy 1991); the ongoing work of a group of researchers at the University of Newcastle-upon-Tyne's Center for Urban and Regional Development Studies (Gillespie and Williams 1988; Hepworth and Waterson 1988); and a number of articles by Mitchell Moss (1986, 1988)[11].

Moss has made the following propositions about the current and prospective impacts of telecommunications on regional economic development:

1. Telecommunications is producing a new urban hierarchy. A small number of cities, having the most sophisticated and extensive infrastructures, will serve as international information capitals (Moss 1988, 271).

2. Telecommunications investments will be concentrated in those metropolitan areas with information-intensive industries, leading to heightened disparities between urban and rural telecommunications systems (Moss, 1988, 263).

3. There will be substantial variations in the quality and range of service offerings, depending on the size and orientation of the market (Moss 1988, 263).

4. Innovations in telecommunications transmission and switching equipment will exhibit a pattern of diffusion based on size and information intensity (Moss 1988, 262).

These propositions appear more trenchant in the light of a body of futurist literature concerning the probable decentralizing effects of telecommunications. The emerging pattern of abandonment of earlier regulatory policies that promoted greater geographical uniformity of the telecommunications infrastructure and service offerings is a development that would bolster Moss' arguments.

Moss sought to substantiate his claims on the basis of several simple empirical studies. In one study[12], he used the number of facsimile machines in large U.S. cities as a proxy for the presence of telecommunications-intensive firms. His analysis consisted of simply showing that there is not a strong correlation between population rank and rank of facsimile penetration. He developed another measure of information-based activity based on document deliveries to and from Japan and the largest metropolitan areas of the U.S. carried by DHL Worldwide, Ltd. (Moss 1988, 267–70). He uses this data to conclude that information flows are highly concentrated to and from a limited number of large cities.

[11] The Director of the Urban Research Center at New York University.

[12] Using data from *Official Facsimile User's Directory, 1985* (New York: FDP Associates 1986) (Moss 1988, 266)

Chapter 5

Modeling Innovation Diffusion in the Telecommunications Sector: A Spatial Econometric Analysis of Equal Access Implementation

5.1 Objective

This chapter sets out an analytical framework for modeling the post-divestiture transition to Equal Access in the U.S. telecommunications sector. The main objective of the modeling effort is to address the following theoretical and empirical issues that have been formulated on the basis of the review and assessment of the literature concerning innovation diffusion and regional development presented in the preceding chapter:

1. Within a core/periphery paradigm, is there regional bias in the pace of technological change in peripheral areas?

2. How constraining is the spatial configuration of the existing telecommunications infrastructure?

3. How well does the 'information intensity' of a territory's economic structure explain its celerity of telecommunications innovation?

4. How strong are economies of agglomeration in explaining innovation patterns?

5. Do larger firms exhibit a tendency to implement innovations more rapidly than smaller firms?

6. How sensitive are empirical results to: temporal and spatial scales of measurement; distributional assumptions; variables considered; and other specification issues?

Considerable attention will be given to operationalizing the core/periphery framework. A secondary objective of the chapter is to present methodologies for dealing with econometric problems associated wih spatial dependence and spatial heterogenity. Anselin (1988) has provided an extremely useful survey of methods to apply for modeling data observed in a spatial context, some of which are applied for this case study.

5.2 The Data

5.2.1 The Equal Access Implementation Schedule Data

This section of the chapter describes the Equal Access schedule data that forms the dependent variable of the model of innovation diffusion to be elaborated below. The conversion to Equal Access capability is a process that takes place at end office switches of local exchange carriers (LECs). At least six months prior to the cut-over of a local exchange, the LECs are required by the Federal Communications Commission (FCC) to notify the affected inter-exchange carriers (IECs). I have utilized an AT&T database of this information as it existed as of December 1990, by which time the majority of the switches undergoing implementation of Equal Access had already been converted. According to the National Exchange Carriers Association (NECA), as of December 1990 there were 22,371 end office switches in the continental U.S. 13,554 (60.6%) of these are included in the AT&T Equal Access database. Table 5.2 shows that the proportion of switches included in the Equal Access database is higher for larger firms. The database specifies the cut-over date, i.e., the date on which direct connection capability of customers with their selected IEC is implemented. For modeling purposes, the date has been re-expressed as the number of days since June 1, 1984[1].

Identifiable Cross-Sectional Segmentations

Switches are identified by an 11 character code maintained by the National Exchange Carriers Association (NECA). The first 6 characters identify the city (4 bytes) and state (2 bytes) in which the switch is located. The remaining 5 characters of the code identify the building and the specific switch. The database further identifies the company that owns the switch and the type of switch (electronic, remote, cross-bar, step-by-step, or unknown type[2] . An end-office in which a switch resides can be further referenced according to its county, metropolitan area, state, local exchange carrier, and holding company. End offices are located in space by vertical and horizontal coordinates, which also provide a basis for computing distances between end offices[3].

[1]The first occurrence of Equal Access implementation was in July 1984. The number of days can of course be aggregated to discrete numbers of months or quarters. Another way of modeling this information in a more temporally aggregate manner would be in terms of the proportion of a territory's (or firm's) end offices (or customers) that have cut-over by specified points in time.

[2]The database sometimes includes the trademark name and model of the switch and other times only shows a more generic listing.

[3]Most long distance telecommunications prices are distance sensitive, i.e. tariff rates vary by mileage bands. The mileage band of a particular call is computed on the basis of the coordinates of the originating and terminating end-offices.

TABLE 5.1: Switching Stations by Size of Company

Company Size (by # of Switching Stations)	Number of Companies	Switching Stations Total	In Schedule	Known Date	% Known Date
unidentified companies		0	3,656	2,548	69.7%
1	487	487	88	87	98.9%
2 to 10	687	3,007	367	354	96.5%
11 to 20	102	1,444	192	156	81.3%
21 to 100	93	4,262	1,151	1,033	89.7%
101 to 200	36	5,278	2,855	2,344	82.1%
201 to 300	14	3,207	2,278	1,920	84.3%
301 to 400	5	1,602	1,039	872	83.9%
Over 400	5	3,084	1,928	1,670	86.6%
TOTAL	1,429	22,371	13,554	10,984	81.0%

Source:
(Col. 1-2) National Exchange Carriers Association Tariff 4 database
(Col. 3-4) AT&T Cutover Schedule database

TABLE 5.2: Distribution of Switching Stations

Company Size (by # of Switching Stations)	Distribution of Companies	Switching Stations Total	In Schedule	Known Date
unidentified companies		0.0%	27.0%	23.2%
1	34.1%	2.2%	0.6%	0.8%
2 to 10	48.0%	13.4%	2.7%	3.2%
11 to 20	7.1%	6.5%	1.4%	1.4%
21 to 100	6.5%	19.1%	8.5%	9.4%
101 to 200	2.5%	23.6%	21.1%	21.3%
201 to 300	1.0%	14.3%	16.8%	17.5%
301 to 400	0.3%	7.2%	7.7%	7.9%
Over 400	0.3%	13.8%	14.2%	15.2%
TOTAL	100.0%	100.0%	100.0%	100.0%

Notation

In the models to be presented below, extensive use will be made of the following notation. Denoting end office, county, firm, and type of switch by the subscripts a, c, f, and k, respectively, the random variable for the natural logarithm of the duration before equal access implementation, can be written:

$$T_{acfk}$$

$a = 1, \ldots, N^a_{cf}$

$c = 1, \ldots, N^c_f$

$f = 1, \ldots, F$

$k = 1, \ldots, K$

where:

$N^a_{cf} \equiv$ number of end offices of firm f in county c

$F \equiv$ number of firms[4]

$K \equiv$ number of types of switches[5]

$N^c_f \equiv$ the number of counties in the service territory of firm f

The number of switches of type k owned by firm f in county c will be donoted by N^k_{cf}.

5.2.2 Additional Covariates

The speed of transition to equal access is hypothesized to be related to: end-office profitability (to both LECs and IECs; size of firm; agglomeration economies and level of urbanization; and economic structure and dynamics. Some of the variables used to operationalize these effects are measurable at the end-office level. Other series, such as sectoral employment and personal income components were only obtainable at the county level. All of the independent variables that will be considered do not change temporally within the dataset[6]. That is, they are cross-sectionally varying but duration-invariant covariates. Dynamic considerations are introduced through utilization of county-specific employment growth rates.

Variables measured at the end-office level

Among the variables that were obtainable at the end-office level were cross-sectional snapshots of AT&T[7] telecommunications revenues (R), messages (M), and customers

[4]Firms will be defined as Bell or independent regional holding companies (aggregations of LECs).

[5]The types of switches to be analyzed are ESS, Cross-Bar, Step-by-Step, Remote, and unknown.

[6]This limitation was imposed as a practical matter to make the dataset more managable from a computer storage and expense standpoint. Furthermore, my main research interest in the present context is related to sensitivity to cross-sectional variation. In any case, the county-level data was available only on an annual basis. The telecommunications traffic volume data at the end-office level of detail was only accessable for a single snapshot.

[7]In the present context it would be preferable to be able to utilize industry data including the telecommunications traffic of all IEXs as well as each LEC's intra-LATA volumes. Unfortunately, only AT&T data was obtainable, on a proprietary basis.

(C). These variables can be disaggregated by customer class (b)[8], and jurisdiction[9]. To account for agglomeration and proximity effects several additional variables also measurable at the end-office spatial scale are introduced. One of these is simply the number of a given LEC's end-offices in the same city. Another is the euclidian distance between an end office and the nearest 'point-of-presence (POP)' of an interexchange carrier. A POP is an IEC owned building housing the switching and transmission equipment for linking its network with the local exhange carrier's network. The distance from end office a of firm f to the nearest POP of interexchange carrier i will be denoted D_{afi}.

Variables measured at the county level

Among the variables measured at the county level are employment at the 1-digit SIC level.[10] E_{cst} will be used to denote employment of sector s in county c for time period t. The employment variables are defined as 5 year averages for either of two periods 1979-1983 or 1984-1988. The 1984 demarcation point was chosen primarily because of the divestiture of the Bell Operating Companies from AT&T in that year.

In their recent book on the measurement and assessment of U.S. productivity, Baumol, Blackman, and Wolff (1989) have provided a penetrating critique of the contention that the U.S. is becoming an information economy. Their analysis proceeds as follows. First, using U.S. census data, they assign occupational classifications to four basic categories of activities: knowledge production; data processing; supply of services; and goods production. Information workers are defined to consist of knowledge and data workers. Data that they reported for 1970 and 1980 are reproduced below as Table 5.3. The table shows that by 1980, 52.5 percent of U.S.

TABLE 5.3: Employment composition

Category	Employment (thousands)		Percent of total	
	1970	1980	1970	1980
Information	36,091	51,125	48.6 %	52.5 %
Services	11,198	15,648	15.1 %	16.1 %
Goods	27,010	30,596	36.3 %	31.4 %
Total	74,299	97,369	100.0 %	100.0 %

Source:Baumol, Blackman, and Wolff [1989, p.147]

employment was made up of information workers. The corresponding value for 1960 was 42.2 percent. It is figures such as these that are typically cited in characterizing the evolution toward an information economy. Baumol and his coworkers next step, using Bureau of Economic Analysis' industry/occupational matrices, was to determine the sectoral distribution of knowledge and data workers. Table 5.4 displays information workers shares of total employment by major industry for 1970 and 1980.[11]

[8]Business and Residence. Residence customers and their associated revenues can be split still further according to monthly bill sizes. This level of detail was not, however, available for business customers.

[9]The dimensions of jurisdiction are: intrastate (Intra-LATA calls within one state); interstate (calls between states); and international (calls originated in the U.S. only).

[10]The sectoral employment categories are: agricultural services; construction; finance, insurance, and real estate; farming; civilian federal government; military federal government; state and local government; manufacturing; mining; retail trade; services; transportation, communication, and utilities; and wholesale trade.

[11]The 1980 information worker proportions of sectoral employment will be used to construct county-level series on information employment for incorporation into the econometric analysis of Equal Access implementation.

TABLE 5.4: Information workers' share of employment by major industry

Sector	1970	1980
Agriculture	6.3 %	9.6 %
Mining	33.4 %	38.9 %
Construction	24.3 %	27.4 %
Nondurable manufacturing	33.2 %	35.8 %
Durable manufacturing	36.8 %	38.2 %
Transportation	43.5 %	46.6 %
Trade	59.5 %	60.9 %
Finance, insurance, and real estate	90.9 %	91.4 %
Services	55.1 %	58.9 %
Government	66.8 %	66.7 %
Total (weighted average)	48.6 %	52.5 %

Source:Baumol, Blackman, and Wolff [1989, p.150]

They then go on to show that changes in the proportion of the labor force comprised by information workers can be decomposed into three parts:

input substitution effect. The change in the information workers' proportion of each industry's total employment. That is, as production processes within industries become more information intensive there is a substitution of information occupations for other forms of employment.

relative labor productivity effect. The change for each industry relative to all industries, in the ratio of employment to output. Information intensive industries have tended to be subject to slow productivity growth.

output composition effect. The change in each industry's share of total output.

A little algebra clarifies the derivation of their three-part breakdown. They start from an identity, by industry, of the information workers' share of total employment:

$$\frac{I_s}{\sum E_s} = \frac{I_s}{E_s} \cdot \frac{E_s / Y_s}{\sum E_s / \sum Y_s} \cdot \frac{Y_s}{\sum Y_s}$$

where:

$I_s =$ Information workers in industry s

$E_s =$ Total employment in industry s

$Y_s =$ Total output of industry s

TABLE 5.5: Decomposition of change in information employment proportion

1970 - 1980 period		
Effect	Decomposition of change in employment compostion (in percentage points)	share of total change
Input substitution	2.40	61.0 %
Productivity lag	1.04	26.6 %
Output composition	0.49	12.4 %
Total change	3.93	100.0 %

Source:Baumol, Blackman, and Wolff [1989, p.155]

The algebraic expression of the three effects are then:

$$\begin{aligned}
\left[\Delta \frac{I_s}{\sum E_s}\right] &= \Delta \left[\frac{I_s}{E_s}\right] \cdot \frac{E_s/Y_s}{\sum E_s/\sum Y_s} \cdot \frac{Y_s}{\sum Y_s} \\
&+ \frac{I_s}{E_s} \cdot \Delta \left[\frac{E_s/Y_s}{\sum E_s/\sum Y_s}\right] \cdot \frac{Y_s}{\sum Y_s} \\
&+ \frac{I_s}{E_s} \cdot \frac{E_s/Y_s}{\sum E_s/\sum Y_s} \cdot \Delta \left[\frac{Y_s}{\sum Y_s}\right]
\end{aligned}$$

As the data in Table 5.5 indicates, the expansion in information-related employment is only marginally attributable to a shifting demand toward products having a high information content. 61% of the changing share of information employment is due to the changing structure of occupations, and 26.6% due to the relatively lagging productivity growth of information intensive industries.

The I_s/E_s coefficients are utilized in the modeling of Equal Access. Explicit use is not made of the decomposition just described. However, based on the results of Baumol and his co-workers, the exclusion of productivity and output measures from the analysis would seem not to be a fundamental omission.

Population percentages classified as in central cities, urban areas, or rural areas were used to define dummy variables for urban and suburban counties.

Variables measured at the SMSA-level

Attempts of various authors to operationalize measures of core/peripheral status were discussed in section 3 of Chapter 4. In regional science, the core/peripheral paradigm has generally been defined with respect to standard metroplitan statistical areas (SMSAs). Three separate SMSA-level location quotient indices have been utilized to give an 'information economy' slant to measuring regional imbalance and differentiation. The three types of location quotients to be utilized in modeling will be referred to as: *information employment*; *jurisdictional orientation*; and *customer-class revenue composition*. Before describing these indices meant to capture dimensions of regional information intensity, I will briefly digress to a discussion of sectoral employment location quotients, the more familiar type of location quotient.

Employment Location Quotients

An employment location quotient for sector s in SMSA m is defined as that sector's share of total employment in SMSA m relative to the national level sectoral share. This is also equivalent to the SMSA's share of national sector s employment relative to that SMSA's share of national total employment. That is, denoting the employment location quotient for sector s in SMSA m at time t as $Q(E)_{mst}$:

$$Q(E)_{mst} = \frac{E_{mst}/E_{mt}}{E_{st}/E_t} = \frac{E_{mst}/E_{st}}{E_{mt}/E_t}$$

where:

$$\begin{aligned}
E_{mt} &= \sum_s E_{mst} \\
E_{st} &= \sum_m E_{mst}
\end{aligned}$$

$$E_t = \sum_m \sum_s E_{mst}$$

Location quotients capture two facets of an area's industrial structure, namely concentration and specialization (Watkins 1978, 64) . Concentration refers to the share of the national economy located in a local economy. Specialization refers to the proportion of the local labor force employed in a particular sector. From the formula above, location quotients can be thought of as either a ratio of SMSA specialization to national specialization, or as sectoral concentration relative to aggregate concentration. Location quotients have been used in regional science as crude indicators of an area's extent of integration in national markets. If a local economy's sectoral specialization exceeds the national average, this has been taken to indicate a propensity to 'export' the output of that sector. Such interpretations would only be valid if areas being compared faced similar demand functions and productivities. A revised form of location quotient would be to use a regional economy rather than the national economy as the benchmark. As Watkins (1978, 280) pointed out, it is also appropriate to avoid double counting by removing local employment from the benchmark economy. Incorporating this adjustment, as well as specifying the benchmark in terms of the regions defined by the aggregation of the SMSAs and non-SMSA counties making up the Regional Holding Companies' service territories (referenced by the subscript h), sectoral employment location quotients could be redefined as:

$$Q(E)_{mst} = \frac{E_{mst}/E_{mt}}{(E_{hst}-E_{mst})/(E_{ht}-E_{mt})}$$

where:

$$\begin{aligned} E_{mt} &= \sum_s E_{mst} \\ E_{hst} &= \sum_{m \in h} E_{mst} \\ E_{ht} &= \sum_{m \in h} \sum_s E_{mst} \end{aligned}$$

Another form of benchmark, which I utilize in the models to be presented below, is to classify SMSAs into size groups. Large SMSA's are expected to have a more diversified employment base than smaller ones.

Information Employment Location Quotient

Based on the sector-specific information worker shares of total employment presented above in Table 5.4, the number of information workers I in an SMSA can be computed as:

$$I_{mt} = \sum_s \phi_s E_{mst}$$

where:

ϕ_s = the information workers proportion of total employment in sector s.

A location quotient for information employment, with a national benchmark, is defined as:

$$Q(I)_{mt} = \frac{I_{mt}/E_{mt}}{(I_t - I_{mt})/(E_t - E_{mt})}$$

If the location quotient is defined with respect to a size-of-employment SMSA group, denoted by a g subscript, the revised expression would be:

$$Q(I_g)mt = \frac{I_{mt}/E_{mt}}{(I_{gt} - I_{mt})/(E_{gt} - E_{mt})}$$

where:

$$E_{gt} = \sum_{m \in g} E_{mt}$$

$$I_{gt} = \sum_{m \in g} I_{mt}$$

Five groups were defined according to the ranges of employment shown in Table 5.6.

TABLE 5.6: Groups of SMSA's According to Average Total Employment

group	*number*	*employment range*
1	71	4,578–59,857
2	73	60,076–99,409
3	72	100,110–181,087
4	73	181,701–476,444
5	74	481,619–4,799,052
total	363	

Telecommunications Demand Location Quotients

It is also possible to measure economic structure through another form of location quotient that provides a more direct measure of regional integration. A major contention of this thesis is that there will be greater pressure for rapid telecommunications innovations in those areas more inserted in national and global markets. Before proceding with further discussion of this issue, the expression for SMSA-level location quotients based on the jurisdictional composition of business telecommunications demand will be introduced. Using notation introduced previously,[12] these location quotients are defined (with a national benchmark)[13]:

$$Q(M)_{b_B jm} = \frac{M_{b_B jm}/M_{b_B m}}{(M_{b_B j} - M_{b_B jm})/(M_{b_B} - M_{b_B m})}$$

where:

$$M_{b_B m} = \sum_j M_{b_B jm}$$

$$M_{b_B} = \sum_j \sum_m M_{b_B jm}$$

For the purpose of defining these jurisdictional-orientation location quotients, the interstate, offshore, and international jurisdictions have been grouped together

[12]The subscripted subscript notation, b_B, is used to denote restriction of the customer class (b) to Business customers. b_R will be used to denote Residence customers.

[13]The expression for the size-group benchmark variable should be obvious by analogy with the information employment location quotient defined relative to size group.

to be contrasted with intrastate. That is, two, rather than four, $Q(M)_{b_Bjm}$ are defined for each SMSA.

The final type of location quotient used to operationalize the information economy twist to the core/periphery paradigm, is defined in relation to customer class shares of total interLATA telecommunications revenues:

$$Q(R)_{bm} = \frac{R_{bm}/R_m}{(R_b - R_{bm})/(R - R_m)}$$

where:

$$\begin{aligned} R_{bm} &= \sum_j R_{bjm} \\ R_b &= \sum_j \sum_m R_{bjm} \\ R &= \sum_b \sum_j \sum_m R_{bjm} \end{aligned}$$

This notation would be a bit cumbersome for use in reporting regression results. The notation was introduced to clarify the definition of the variables. To simplify somewhat, in the tables to be presented, the jurisdictional-orientation location quotients will be represented by $Q(M_1)$ (for intrastate) and $Q(M_2)$ (for non-intrastate, i.e., interstate, offshore, and international). The location quotient for the business customer class proportion of total revenue will be referenced by $Q(R_B)$.

Noyelle-Stanback Groups of SMSAs

As an alternative to classifying SMSAs according to the values of the location quotients described above, Noyelle and Stanback's schema described in Chapter 4 can be utilized. Their 11-way classification of SMSAs were grouped into 4 dummy variables as follows:

1. **Nodal Center**
   - National Nodal
   - Regional Nodal
   - Subregional Nodal
2. **Specialized Service Centers**
   - Functional Nodal
   - Government-Education
   - Education-Manufacturing
3. **Production Centers**
   - Manufacturing
   - Industrial-Military
   - Mining-Industrial
4. **Consumer-Oriented**
   - Residential

TABLE 5.7: AMERITECH (IL,IN): Employment and Principal Components Variables

state	*smsa*	*employment*	*Noyelle-Stanback group*
IL	KANKAKEE	41,358	not classified
IL	DECATUR	63,650	not classified
IL	BLOOMINGTON-NORMAL	67,439	not classified
IL	CHAMPAIGN-URBANA-RANTOUL	103,258	not classified
IL	DAVENPORT-ROCK ISLAND-MOLINE	107,003	Manufacturing
IL	SPRINGFIELD	114,815	not classified
IL	JOLIET	122,136	not classified
IL	AURORA-ELGIN	159,250	not classified
IL	LAKE COUNTY	245,963	not classified
IL	non-smsa	845,461	not classified
IL	CHICAGO	3,422,631	National Nodal
IN	CINCINNATI	12,508	Regional Nodal
IN	KOKOMO	53,509	not classified
IN	BLOOMINGTON	57,130	not classified
IN	MUNCIE	57,920	not classified
IN	ANDERSON	60,315	not classified
IN	TERRE HAUTE	63,789	not classified
IN	LAFAYETTE	69,632	not classified
IN	LOUISVILLE	73,841	not classified
IN	ELK HART-GOSHEN	104,700	not classified
IN	SOUTH BEND-MISHAWAKA	127,324	Education-Manufacturing
IN	EVANSVILLE	132,827	Manufacturing
IN	FORT WAYNE	198,101	Functional Nodal
IN	GARY-HAMMOND	251,114	Manufacturing
IN	INDIANAPOLIS	696,740	Regional Nodal
IN	non-smsa	769,011	not classified

- Resort-retirement

As can be seen from Tables 5.7–5.16, many SMSAs are not included in Noyelle-Stanback's framework, which was limited to 140 metropolitan areas. The unclassified SMSAs are not assigned an explicit dummy variable; the four explicit dummies are then interpreted in relation to the unclassified category.

TABLE 5.8: AMERITECH (KY, MI, OH, WI): Employment and Principal Components Variables

state	*smsa*	*employment*	*Noyelle-Stanback group*
KY	EVANSVILLE	21,346	not classified
KY	HUNTINGTON-ASHLAND	46,871	Manufacturing
KY	CLARKSVILLE-HOPKINSVILLE	50,378	not classified
KY	CINCINNATI	107,723	not classified
KY	LEXINGTON-FAYETTE	211,376	Industrial-Military
KY	LOUISVILLE	426,171	Functional Nodal
KY	non-smsa	709,322	not classified
MI	JACKSON	60,076	not classified
MI	BATTLE CREEK	63,269	not classified
MI	MUSKEGON	67,793	not classified
MI	BENTON HARBOR	76,665	not classified
MI	KALAMAZOO	116,048	Functional Nodal
MI	SAGINAW-BAY CITY-MIDLAND	175,530	not classified
MI	ANN ARBOR	184,257	Education-Manufacturing
MI	FLINT	204,821	Manufacturing
MI	LANSING-EAST LANSING	216,791	Government-Education
MI	GRAND RAPIDS	373,744	Manufacturing
MI	non-smsa	683,284	not classified
OH	HUNTINGTON-ASHLAND	14,014	not classified
OH	WHEELING	26,172	not classified
OH	PARKERSBURG-MARIETTA	27,875	not classified
OH	STEUBENVILLE-WEIRTON	30,520	not classified
OH	LIMA	83,055	not classified
OH	LORAIN-ELYRIA	100,968	Manufacturing
OH	HAMILTON-MIDDLETOWN	107,255	not classified
OH	CANTON	184,727	Manufacturing
OH	YOUNGSTOWN-WARREN	223,284	Manufacturing
OH	AKRON	305,642	Functional Nodal
OH	DAYTON-SPRINGFIELD	501,829	Functional Nodal
OH	CINCINNATI	650,419	not classified
OH	COLUMBUS	751,345	Regional Nodal
OH	non-smsa	939,748	not classified
OH	CLEVELAND	1,021,441	Regional Nodal
WI	DULUTH	18,110	Mining-Industrial
WI	MINNEAPOLIS-ST. PAUL	19,294	Regional Nodal
WI	EAU CLAIRE	23,577	not classified
WI	KENOSHA	48,821	not classified
WI	SHEBOYGAN	55,204	not classified
WI	WAUSAU	58,841	not classified
WI	LA CROSSE	59,857	not classified
WI	RACINE	81,092	not classified
WI	APPLETON-OSHKOSH-NEENAH	155,544	Manufacturing
WI	non-smsa	558,915	not classified
WI	MILWAUKEE	805,189	Functional Nodal

TABLE 5.9: BELL ATLANTIC: Employment and Principal Components Variables

state	*smsa*	*employment*	*Noyelle-Stanback group*
DE	non-smsa	108,737	not classified
DE	WILMINGTON	252,394	not classified
MD	WILMINGTON	20,821	not classified
MD	CUMBERLAND	33,225	not classified
MD	HAGERSTOWN	57,546	not classified
MD	non-smsa	162,751	not classified
MD	WASHINGTON	851,789	Government-Educatiion
MD	BALTIMORE	1,284,630	Regional Nodal
NJ	WILMINGTON	31,382	not classified
NJ	ALLENTOWN-BETHLEHEM	39,982	not classified
NJ	ATLANTIC CITY	192,759	not classified
NJ	TRENTON	205,050	Government-Education
NJ	JERSEY CITY	272,665	Functional Nodal
NJ	MONMOUTH-OCEAN	391,975	not classified .
NJ	PHILADELPHIA	500,133	Regional Nodal
NJ	MIDDLESEX-SOMERSET-HUNTERDON	565,220	not classified
NJ	BERGEN-PASSAIC	775,289	not classified
NJ	NEWARK	1,101,162	Functional Nodal
PA	SHARON	49,949	not classified
PA	WILLIAMSPORT	56,420	not classified
PA	ALTOONA	60,467	not classified
PA	BEAVER COUNTY	63,753	not classified
PA	JOHNSTOWN	93,793	Mining-Industrial
PA	ERIE	132,141	Manufacturing
PA	READING	175,359	Manufacturing
PA	YORK	199,842	Manufacturing
PA	LANCASTER	216,055	Manufacturing
PA	SCRANTON-WILKES-BARRE	329,786	not classified
PA	HARRISBURG-LEBANON-CARLISLE	334,174	Government-Education
PA	non-smsa	659,807	not classified
PA	PITTSBURGH	1,015,971	Functional Nodal
PA	PHILADELPHIA	1,982,903	Regional Nodal
VA	CHARLOTTESVILLE	4,578	not classified
VA	ROANOKE	91,179	not classified
VA	WASHINGTON	241,087	Government-Education
VA	non-smsa	372,505	not classified
VA	RICHMOND-PETERSBURG	454,666	Subregional Nodal
VA	NORFOLK-VIRGINIA BEACH-NEWPORT NEWS	712,455	Industrial-Military

TABLE 5.10: BELL SOUTH (AL, FL, GA, LA): Employment and Principal Components Variables

state	*smsa*	*employment*	*Noyelle-Stanback group*
AL	MONTGOMERY	13,057	not classified
AL	COLUMBUS	15,153	not classified
AL	FLORENCE	58,551	not classified
AL	TUSCALOOSA	63,209	not classified
AL	DOTHAN	64,845	not classified
AL	HUNTSVILLE	139,169	Industrial-Military
AL	MOBILE	206,513	Subregional Nodal
AL	BIRMINGHAM	443,613	Subregional Nodal
AL	non-smsa	484,376	not classified
FL	PANAMA CITY	62,410	not classified
FL	NAPLES	64,439	not classified
FL	OCALA	71,480	not classified
FL	FORT WALTON BEACH	73,864	not classified
FL	BRADENTON	78,227	not classified
FL	FORT PIERCE	90,057	not classified
FL	GAINESVILLE	105,358	not classified
FL	TALLAHASSEE	121,071	not classified
FL	SARASOTA	133,661	not classified
FL	FORT MYERS	136,567	not classified
FL	PENSACOLA	156,710	Industrial-Military
FL	MELBOURNE-TITUSVILLE-PALM BAY	172,208	not classified
FL	LAKELAND-WINTER HAVEN	172,456	Mining-Industrial
FL	non-smsa	331,453	not classified
FL	WEST PALM BEACH-BOCA RATON-DELRAY B	408,921	Resort-Retirement
FL	JACKSONVILLE	476,444	Subregional Nodal
FL	ORLANDO	544,380	Resort-Retirement
FL	FORT LAUDERDALE-HOLLYWOOD-POMPANO	575,595	Resort-Retirement
FL	TAMPA-ST. PETERSBURG-CLEARWATER	964,235	Resort-Retirement
FL	MIAMI-HIALEAH	1,011,616	Regional Nodal
GA	ALBANY	61,239	not classified
GA	ATHENS	71,176	not classified
GA	COLUMBUS	118,950	not classified
GA	SAVANNAH	120,547	not classified
GA	AUGUSTA	140,112	Industrial-Military
GA	MACON-WARNER ROBINS	140,930	not classified
GA	non-smsa	756,538	not classified
GA	ATLANTA	1,472,016	Regional Nodal
LA	ALEXANDRIA	60,767	not classified
LA	MONROE	68,194	not classified
LA	LAKE CHARLES	71,615	not classified
LA	HOUMA-THIBODAUX	75,399	not classified
LA	LAFAYETTE	118,359	not classified
LA	SHREVEPORT	182,643	Subregional Nodal
LA	BATON ROUGE	258,401	Government-Education
LA	non-smsa	487,293	not classified
LA	NEW ORLEANS	651,440	Regional Nodal

TABLE 5.11: BELL SOUTH (MS, NC, SC, TN, WV): Employment and Principal Components Variables

state	*smsa*	*employment*	*Noyelle-Stanback group*
MS	MEMPHIS	20,383	Subregional Nodal
MS	PASCAGOULA	51,753	not classified
MS	BILOXI-GULFPORT	99,409	not classified
MS	JACKSON	209,073	Subregional Nodal
MS	non-smsa	693,598	not classified
NC	BURLINGTON	59,609	not classified
NC	WILMINGTON	65,801	not classified
NC	JACKSONVILLE	73,061	not classified
NC	ASHEVILLE	94,349	not classified
NC	HICKORY	136,769	not classified
NC	FAYETTEVILLE	138,535	not classified
NC	RALEIGH-DURHAM	429,803	Government-Education
NC	GREENSBORO-WINSTON-SALEM-HIGH POINT	548,371	not classified
NC	CHARLOTTE-GASTONIA-ROCK HILL	551,495	not classified
NC	non-smsa	1,198,456	not classified
SC	CHARLOTTE-GASTONIA-ROCK HILL	53,053	not classified
SC	AUGUSTA	53,443	not classified
SC	FLORENCE	60,231	not classified
SC	ANDERSON	61,265	not classified
SC	GREENVILLE-SPARTANBURG	151,729	Manufacturing
SC	CHARLESTON	250,967	Industrial-Military
SC	COLUMBIA	269,316	Government-Education
SC	non-smsa	574,704	not classified
TN	CLARKSVILLE-HOPKINSVILLE	28,919	not classified
TN	JOHNSON CITY-KINGSPORT-BRISTOL	160,264	Manufacturing
TN	CHATTANOOGA	181,701	Manufacturing
TN	KNOXVILLE	300,168	Functional Nodal
TN	MEMPHIS	481,780	not classified
TN	NASHVILLE	547,037	Subregional Nodal
TN	non-smsa	611,344	not classified
WV	CUMBERLAND	8,583	not classified
WV	STEUBENVILLE-WEIRTON	28,602	not classified
WV	WHEELING	44,020	not classified
WV	PARKERSBURG-MARIETTA	44,998	not classified
WV	HUNTINGTON-ASHLAND	63,792	not classified
WV	CHARLESTON	126,644	not classified
WV	non-smsa	411,705	not classified

TABLE 5.12: NYNEX: Employment and Principal Components Variables

state	*smsa*	*employment*	*Noyelle-Stanback group*
CT	NEW LONDON-NORWICH	142,482	not classified
CT	BRIDGEPORT-STAMFORD-NORWALK-DANBURY	522,802	Funcional Nodal
CT	HARTFORD-NEW BRITAIN-MIDDLETON-BRISTOL	711,229	Functional Nodal
MA	PITTSFIELD	75,909	not classified
MA	non-smsa	144,462	not classified
MA	NEW BEDFORD-FALL RIVER-ATTLEBORO	237,775	Manufacturing
MA	SPRINGFIELD	303,509	not classified
MA	WORCESTER-FITCHBURG-LEOMINSTER	340,315	Manufacturing
MA	BOSTON-LAWRENCE-SALEM-LOWELL-BROCKTON	1,836,723	Regional Nodal
ME	LEWISTON-AUBURN	49,616	not classified
ME	BANGOR	73,929	not classified
ME	non-smsa	325,793	not classified
NH	non-smsa	147,805	not classified
NH	PORTSMOUTH-DOVER-ROCHESTER	168,883	not classified
NH	MANCHESTER-NASHUA	205,442	not classified
NY	ELMIRA	42,015	not classified
NY	GLENS FALLS	56,429	not classified
NY	NIAGARA FALLS	94,300	not classified
NY	ORANGE COUNTY	124,029	not classified
NY	POUGHKEEPSIE	136,096	not classified
NY	BINGHAMTON	138,958	Manufacturing
NY	UTICA-ROME	148,354	Government-Education
NY	SYRACUSE	344,774	Subregional Nodal
NY	ALBANY-SCHENECTADY-TROY	435,431	Government-Education
NY	BUFFALO	489,602	Manufacturing
NY	ROCHESTER	536,917	Functional Nodal
NY	non-smsa	691,610	not classified
NY	NASSAU-SUFFOLK	1,379,743	Residential
NY	NEW YORK	4,738,159	National Nodal
RI	PROVIDENCE-PAWTUCKET-WOONSOCKET	481,619	Manufacturing
VT	non-smsa	224,374	not classified

TABLE 5.13: PACIFIC TELESIS: Employment and Principal Components Variables

state	*smsa*	*employment*	*Noyelle-Stanback group*
CA	YUBA CITY	47,007	not classified
CA	REDDING	57,390	not classified
CA	CHICO	70,004	not classified
CA	SANTA CRUZ	104,175	not classified
CA	SACRAMENTO	104,505	Government-Education
CA	VISALIA-TULARE-PORTERVILLE	129,192	not classified
CA	MODESTO	136,578	not classified
CA	VALLEJO-FAIRFIELD-NAPA	165,709	Industrial-Military
CA	SANTA ROSA-PETALUMA	168,904	not classified
CA	SALINAS-SEASIDE-MONTEREY	181,087	Industrial-Military
CA	STOCKTON	187,250	Government-Education
CA	SANTA BARBARA-SANTA MARIA-LOMPOC	200,014	Resort-Retirement
CA	BAKERSFIELD	237,249	Mining-Industrial
CA	OXNARD-VENTURA	269,332	Harrisburg
CA	FRESNO	295,432	Government-Education
CA	RIVERSIDE-SAN BERNARDINO	432,679	Resort-Retirement
CA	non-smsa	517,095	not classified
CA	SAN JOSE	949,499	Functional Nodal
CA	SAN FRANCISCO-OAKLAND	1,182,464	National Nodal
CA	SAN DIEGO	1,197,453	Industrial-Military
CA	ANAHEIM-SANTA ANA	1,332,704	Residential
CA	LOS ANGELES-LONG BEACH	4,799,052	National Nodal
NV	non-smsa	52,876	not classified
NV	RENO	150,066	not classified
NV	LAS VEGAS	318,248	Resort-Retirement

TABLE 5.14: SOUTHWESTERN BELL: Employment and Principal Components Variables

state	*smsa*	*employment*	*Noyelle-Stanback group*
AR	MEMPHIS	17,186	not classified
AR	PINE BLUFF	40,540	not classified
AR	FORT SMITH	82,003	not classified
AR	LITTLE ROCK-NORTH LITTLE ROCK	283,174	Subregional Nodal
AR	non-smsa	444,753	not classified
KS	LAWRENCE	37,055	not classified
KS	TOPEKA	101,284	not classified
KS	KANSAS CITY	232,902	Regional Nodal
KS	WICHITA	265,248	Functional Nodal
KS	non-smsa	579,028	not classified
MO	ST. JOSEPH	45,308	not classified
MO	COLUMBIA	65,510	not classified
MO	JOPLIN	71,125	not classified
MO	SPRINGFIELD	136,824	not classified
MO	KANSAS CITY	555,061	not classified
MO	non-smsa	644,442	not classified
MO	ST. LOUIS	1,114,330	Regioanl Nodal
OK	ENID	34,455	not classified
OK	LAWTON	62,541	not classified
OK	TULSA	394,525	not classified
OK	OKLAHOMA CITY	553,447	Subregional Nodal
OK	non-smsa	565,099	not classified
TX	VICTORIA	38,430	not classified
TX	LAREDO	42,175	not classified
TX	TEXARKANA	43,374	not classified
TX	SHERMAN-DENISON	47,289	not classified
TX	SAN ANGELO	52,627	not classified
TX	BRYAN-COLLEGE STATION	60,119	not classified
TX	ODESSA	62,402	not classified
TX	MIDLAND	67,165	not classified
TX	BRAZORIA	74,359	not classified
TX	ABILENE	74,814	not classified
TX	TYLER	84,632	not classified
TX	GALVESTON-TEXAS CITY	87,170	not classified
TX	LONGVIEW-MARSHALL	87,493	not classified
TX	WACO	95,569	not classified
TX	AMARILLO	104,474	not classified
TX	MCALLEN-EDINBURG-MISSION	117,241	not classified
TX	LUBBOCK	121,380	not classified
TX	KILLEEN-TEMPLE	127,287	not classified
TX	BEAUMONT-PORT ARTHUR	163,430	Manufacturing
TX	CORPUS CHRISTI	169,823	Mining-Industrial
TX	EL PASO	235,326	Industrial-Military
TX	AUSTIN	449,399	Government-Education
TX	non-smsa	631,446	not classified
TX	SAN ANTONIO	646,691	Industrial-Military
TX	non-smsa	1,148,522	not classified
TX	HOUSTON	1,771,258	Regioanl Nodal

TABLE 5.15: USWEST (AZ, CO, IA, ID, MN, MT, ND, NE): Employment and Principal Components Variables

state	*smsa*	*employment*	*Noyelle-Stanback group*
AZ	non-smsa	245,703	not classified
AZ	TUCSON	301,251	Mining-Industrial
AZ	PHOENIX	1,077,195	Regional Nodal
CO	PUEBLO	50,399	not classified
CO	GREELEY	60,580	not classified
CO	FORT COLLINS-LOVELAND	91,051	not classified
CO	BOULDER-LONGMONT	143,496	not classified
CO	non-smsa	198,841	not classified
CO	COLORADO SPRINGS	217,141	Industrial-Military
CO	DENVER	1,056,612	Regional Nodal
IA	OMAHA	34,558	Subregional Nodal
IA	DUBUQUE	49,661	not classified
IA	IOWA CITY	56,659	not classified
IA	WATERLOO-CEDAR FALLS	75,687	not classified
IA	DAVENPORT-ROCK ISLAND-MOLINE	80,766	not classified
IA	CEDAR RAPIDS	100,110	not classified
IA	DES MOINES	244,449	Subregional Nodal
IA	non-smsa	713,562	not classified
ID	BOISE CITY	111,809	not classified
ID	non-smsa	308,945	not classified
MN	ROCHESTER	69,690	not classified
MN	ST. CLOUD	75,510	not classified
MN	DULUTH	91,602	Mining-Industrial
MN	non-smsa	484,124	not classified
MN	MINNEAPOLIS-ST. PAUL	1,447,612	Regional Nodal
MT	GREAT FALLS	41,902	not classified
MT	BILLINGS	67,164	not classified
MT	non-smsa	175,213	not classified
ND	GRAND FORKS	40,027	not classified
ND	BISMARCK	46,452	not classified
ND	FARGO-MOORHEAD	65,800	not classified
NE	SIOUX CITY	12,049	not classified
NE	LINCOLN	126,697	not classified
NE	OMAHA	325,837	not classified
NE	non-smsa	358,100	not classified

TABLE 5.16: USWEST (NM, OR, SD, UT, WA, WY): Employment and Principal Components Variables

state	*smsa*	*employment*	*Noyelle-Stanback group*
NM	LAS CRUCES	49,388	not classified
NM	SANTA FE	65,223	not classified
NM	non-smsa	206,300	not classified
NM	ALBUQUERQUE	275,761	Resort-Retirement
OR	MEDFORD	63,230	not classified
OR	SALEM	124,368	not classified
OR	EUGENE-SPRINGFIELD	133,060	Education-Manufacturing
OR	non-smsa	373,077	not classified
SD	SIOUX FALLS	77,731	not classified
SD	non-smsa	212,345	not classified
UT	non-smsa	105,991	not classified
UT	SALT LAKE CITY-OGDEN	542,528	Subregional Nodal
WA	BELLINGHAM	56,391	not classified
WA	OLYMPIA	67,650	not classified
WA	RICHLAND-KENNEWICK-PASCO	73,239	not classified
WA	BREMERTON	79,750	not classified
WA	VANCOUVER	83,026	not classified
WA	YAKIMA	87,154	not classified
WA	SPOKANE	178,664	Subregional Nodal
WA	non-smsa	380,102	not classified
WA	SEATTLE	1,096,902	Regional Nodal
WY	CASPER	38,975	not classified
WY	non-smsa	42,913	not classified

5.2.3 The Structure of the Disaggregate Dataset

Before proceeding further, several tables will be introduced to help provide a sense of the richness of the dataset utilized. Table 5.17 shows for each state, the number of observations for each Bell and Independent regional holding company. For instance, most of the 934 observations in the dataset for California correspond to end offices in the Pacific Telesis service area (761 observations). GTE and CONTEL also serve California. Wyoming, part of the USWEST territory, only has 14 observations in the dataset. Table 5.18 shows the distribution of types of switching equipment by regional holding company. The sparsity of some of the cells of this table show why running separate regressions by company was restricted to the RBOCs and GTE.

TABLE 5.17: Structure of disaggregate dataset (state by company)

state	*observations by company*	*total*
AL	BELSO=135 ALTEL=3 GTE=22	160
AR	SWBCO=100 ALTEL=15 GTE=19	134
AZ	USWST=119	119
CA	PCTEL=761 CONTL=25 GTE=148	934
CO	USWST=133	133
CT	NYNEX=1 SNET=113	114
DE	BELAT=34	34
FL	BELSO=198 ALTEL=18 CTL=44 GTE=100 UNTEL=56	416
GA	BELSO=185 ALTEL=9 GTE=40	234
IA	USWST=72 CTL=4 CONTL=68 GTE=69	213
ID	USWST=78 GTE=8	86
IL	AMTCH=305 ALTEL=20 CTL=28 CONTL=30 GTE=109	492
IN	AMTCH=155 ALTEL=3 CONTL=77 GTE=83 UNTEL=57	375
KS	SWBCO=67 UNTEL=11	78
KY	BELSO=165 CONTL=12 GTE=44	221
LA	BELSO=228	228
MA	NYNEX=232	232
MD	BELAT=215	215
ME	NYNEX=91	91
MI	AMTCH=299 ALTEL=16 GTE=105	420
MN	USWST=106 CTL=7 CONTL=12 GTE=4 UNTEL=21	150
MO	SWBCO=152 GTE=26 UNTEL=21	199
MS	BELSO=202 ALTEL=2	204
MT	USWST=28	28
NC	BELSO=147 ALTEL=21 CTL=43 CONTL=1 GTE=13 UNTEL=103	328
ND	USWST=55	55
NE	USWST=47 GTE=20 UNTEL=3	70
NH	NYNEX=76	76
NJ	BELAT=215 UNTEL=19	234
NM	USWST=50 GTE=9	59
NV	PCTEL=22 CTL=31 CONTL=8	61
NY	NYNEX=654 ALTEL=23	677
OH	AMTCH=258 BELAT=1 ALTEL=60 CTL=16 GTE=149 UNTEL=81	565
OK	SWBCO=82 GTE=20	102
OR	USWST=103 GTE=27 UNTEL=10	140
PA	BELAT=402 ALTEL=41 CONTL=1 GTE=66 UNTEL=50	560
RI	NYNEX=32	32
SC	BELSO=104 ALTEL=6 CONTL=4 GTE=33 UNTEL=9	156
SD	USWST=49	49
TN	BELSO=190 ALTEL=6 GTE=10 UNTEL=22	228
TX	SWBCO=347 CTL=33 CONTL=1 GTE=191 UNTEL=3	575
UT	USWST=42	42
VA	BELAT=221 CTL=56 CONTL=85 GTE=9 UNTEL=8	379
VT	NYNEX=71	71
WA	USWST=138 CONTL=11 GTE=51 UNTEL=5	205
WI	AMTCH=105 GTE=92	197
WV	BELAT=123 ALTEL=9 GTE=16	148
WY	USWST=14	14

TABLE 5.18: Distribution by Company and Type of Switching Equipment

Regional Bell holding companies							
Company		*Electronic*	*Remote*	*Step-by-step*	*Crossbar*	*Unknown*	*TOTAL*
	#	743	316	4	12	47	1,122
AMERITECH	row %	66.22	28.16	0.36	1.07	4.19	100
	column %	14.62	20.76	0.81	1.27	1.84	39.3
	#	660	230	70	170	81	1,211
Bell Atlantic	row %	54.5	18.99	5.78	14.04	6.69	100
	column %	12.98	15.11	14.23	18.05	3.18	63.55
	#	694	76	13	199	572	1,554
Bell South	row %	44.66	4.89	0.84	12.81	36.81	100
	column %	13.65	4.99	2.64	21.13	22.42	64.83
	#	446	103	86	277	245	1,157
NYNEX	row %	38.55	8.9	7.43	23.94	21.18	100
	column %	8.77	6.77	17.48	29.41	9.6	72.03
	#	356	37	11	106	273	783
Pacific Telesis	row %	45.47	4.73	1.4	13.54	34.87	100
	column %	7	2.43	2.24	11.25	10.7	33.62
	#	457	39	159	64	29	748
Southwestern Bell	row %	61.1	5.21	21.26	8.56	3.88	100
	column %	8.99	2.56	32.32	6.79	1.14	51.8
	#	449	85	128	108	264	1,034
USWEST	row %	43.42	8.22	12.38	10.44	25.53	100
	column %	8.83	5.58	26.02	11.46	10.35	62.24
Independent holding companies							
	#	195	5	10	1	41	252
ALLTEL	row %	77.38	1.98	3.97	0.4	16.27	100
	column %	3.84	0.33	2.03	0.11	1.61	7.92
	#	57	0	0	0	0	57
CBI	row %	100	0	0	0	0	100
	column %	1.12	0	0	0	0	1.12
	#	143	45	0	1	73	262
Centel	row %	54.58	17.18	0	0.38	27.86	100
	column %	2.81	2.96	0	0.11	2.86	8.74
	#	25	52	0	0	258	335
CONTEL	row %	7.46	15.52	0	0	77.01	100
	column %	0.49	3.42	0	0	10.11	14.02
	#	624	426	8	4	421	1,483
GTE	row %	42.08	28.73	0.54	0.27	28.39	100
	column %	12.28	27.99	1.63	0.42	16.5	58.82
	#	88	13	0	0	12	113
SNET	row %	77.88	11.5	0	0	10.62	100
	column %	1.73	0.85	0	0	0.47	3.05
	#	146	95	3	0	235	479
UNTEL	row %	30.48	19.83	0.63	0	49.06	100
	column %	2.87	6.24	0.61	0	9.21	18.93
	#	5,083	1,522	492	942	2,551	10,590
Total	row %	48	14.37	4.65	8.9	24.09	100
	column %	100	100	100	100	100	

5.3 Estimation Issues

5.3.1 Probability Distributions for Duration Data

The econometric modeling of the time until cut-over to Equal Access is an example of an event history analysis, also referred to in the literature as duration or survival analysis. This approach has received a good deal of recent attention by labor economists in empirical studies of phenomena such as duration of unemployment, length of strikes, etc. There also seems to be a growing consensus that it is the 'best practice' technique for modeling innovation diffusion (Rose and Joskow 1988). Modeling of the time before cut-over involves a simple event history, entailing only one change of status, unlike some applications of this modeling framework to multiple shifts of state [14].

Event history data are frequently characterized by the presence of *right-censored*[15] observations, that is observational units that have either not yet experienced a change of status at the close of the period under study, or that were withdrawn from the study group prior to a change of status. The database containing the complete equal access cut-over schedule does contain numerous end-offices with missing values for the cut-over date. However, the analysis is restricted to the Bell Operating Companies and major independents, for which censoring is not a problem.

The hazard function is one of the fundamental tools used to analyze duration data. In the present context, the hazard rate would be the probability of an end office cutting-over at time t, conditional on having not cut-over before t. The hazard function or probability density function are equivalent ways of specifying a distribution for duration data. The log normal, Weibull and Gamma distributions are special cases of the Generalized Gamma distribution. For a single observation t on the random variable T, conditional on a vector of explanatory variables x, the Generalized Gamma density function is:

$$f(t|x) = \frac{ct^{ck-1}}{b(x)^{ck}\Gamma(k)} e^{(-t/b(x))^c}$$

where b is a *scale* parameter, c an k are *shape* parameters and Γ is the Gamma function. The simple Gamma occurs for $c = 1$. The Weibull is obtained for $k = 1$. The lognormal distribution results as k approaches ∞. Without censoring, the log normal model can be estimated with any ordinary least squares software package. Results will be reported for the log normal distribution. Preliminary analyses of the other distributions gave similar enough results to warrant not extending the empirical analysis to a complete investigation of the distributional assumption.

5.3.2 Spatial Econometric Methods

This section introduces some specialized methodologies required for properly modeling spatial processes at a fine scale of geographic detail[16]. Spatial econometrics is not merely the application of familiar econometric methods to issues arising in

[14] Lancaster utilizes the term transition data to broaden the analysis of economic events to the destination at the end of an event (e.g., employment or withdrawal from the labor market at the end of an unemployment spell) as well as to encompass multiple spell and multiple destination data (Lancaster 1990).

[15] *Left-censoring* is said to exist if time origins of some observational units are unknown.

[16] All the standard econometrics textbooks ignore the issues to be presented.

regional economics. Rather, spatial aspects of data frequently preclude a straightforward application of standard techniques. *Spatial dependence*[17], and *spatial heterogeneity* are the affending characteristics. In his comprehensive book on the subject, Anselin (1990, p 10) defines spatial econometrics as: "those methods and techniques that, based on a formal representation of the structure of spatial dependence and spatial heterogeneity, provide the means to carry out the proper specification, estimation, hypothesis testing, and prediction for models in regional science". Spatial dependence is similar to the more accustomed serial correlation problem confronted when analysing time-series data. It is, however, a more complex form of dependence due to the potential for areal data to exhibit multidimensional patterns of correlation. A common heuristic device for thinking about spatial dependence is to visualize movements along a chess board. First order spatial dependence exists if neighboring squares of the chessboard are correlated (whether allowing for rook, bishop, or queen type movements). Spatial dependence can be attributed to: spatial externalities or spill-over effects; the somewhat arbitrary delineation of political jurisdictions or other spatial units of observation; and/or the innate structure of spatial processes.

A very general matrix algebra representation of a spatial linear regression framework for the cross sectional data on Equal Access implementation would be:

$$
\begin{aligned}
T &= \rho W_1 T + X\beta + \varepsilon \qquad (5.1) \\
\varepsilon &= \lambda W_2 \varepsilon + \mu \qquad (5.2)
\end{aligned}
$$

with $\mu \sim N(0, \Omega)$

In the most disaggregate form of the models to be introduced, the T vector is comprised of stacked observations of the natural logarithm of time to cut-over of switches at the end-office level of detail, i.e., T_{acfk}. The W matrices, which are generally treated as being equal, i.e., $W_1 = W_2$, are measures of spatial contiguity. The value of an element of the sqare W matrix is based on whether or not two switches are neighbors. Rather than being composed of ones and zeroes, the elements of the spatial lag matrix W is usually standardized such that the row elements sum to one. An observation from the vector formed as the product WT is then the weighted average of the time to cut-over of the switches that neighbor the corresponding observation in T. ρ and λ measure the extent of spatial correlation in the dependent variable and disturbance term, respectively. These parameters measure spatial dependence. Spatial heterogenity refers to either the heteroskedastic structure of the Ω matrix, or spatial variation in the β parameters. Since the data being utilized consists of groups of cross-sections, spatial heteroskedasticity is expected to be present. Spatial variation in the parameters associated with the explanatory variables is introduced into this regression framework according to the block structure of the X matrix. The X matrix can be thought of as being comprised of blocks of submatrices formed from the observations of the different regional holding companies. Allowing for spatially varying parameters β_h implies a diagonal structure to X, i.e.:

$$
\begin{bmatrix}
X_{h_1} & 0 & \cdots & 0 \\
0 & X_{h_2} & \cdots & 0 \\
\vdots & \vdots & \ddots & 0 \\
0 & 0 & 0 & X_{h_n}
\end{bmatrix}
$$

[17]Also known as spatial autocorrelation.

rather than:

$$\begin{bmatrix} X_{h_1} \\ X_{h_2} \\ \vdots \\ X_{h_n} \end{bmatrix}$$

Software for estimating models based on this framework was not available. As a simplification, for each end-office level observation, a proxy for WT was defined as the mean time to cut-over for the SMSA, exclusive of the time to cut-over for that end-office. The variable was defined to be specific to the regional holding company corresponding to the observation in the database (for the case in which more than one regional holding company serves the same SMSA). That is:

$$Z_{achk} = (\sum_{a} \sum_{c \in m} \sum_{k} T_{achk} - T_{achk}) / (N_{hm} - 1)$$

where:

N_{hm} = the number of observations in the dataset for company h in SMSA m.

5.3.3 Random Coefficient Regression Models

One of the more familiar estimators of cross-sectionally specific parameters in the context of pooled cross-sectional time-series data is Swamy's[18] best linear unbiased predictors (BLUPs). Swamy's estimator can be readily adapted to the present context in which the data is comprised of cross-sections of the holding company cross-sections. That is, for each holding company, there are observations for the end-office level of detail.

The calculation of Swamy's BLUPs can be thought of as a three stage process:

1. Separate regressions could be run for each holding company using ordinary least squares (OLS).

   $$b_h = (X_h' X_h)^{-1} X_h' T_h$$

   The vector of residuals for each holding company are:

   $$\hat{e}_h = T_h - X_h b_h$$

   The covariance matrices at the OLS stage are given by:

   $$\hat{\sigma}_{hh} = \frac{\hat{e}_h' \hat{e}_h}{(N_f - V)}$$

   where V denotes the number of variables comprising X_h. The coefficient estimates and covariance matrices become the raw material for the next step.

2. A mean coefficient vector is computed as a matrix weighted average of the OLS parameters.

   $$\hat{\beta} = \sum_{h=1}^{F} H_h b_h$$

[18] Essentially the same notation and exposition as in (Judge, et al.) will be used, except to avoid confusion with the notation employed in the previous section, H rather than W will be used for the weight matrix. Also, the dependent variable, the duration before Equal Access implementation, will be represented by the notation previously introduced, rather than the conventional y.

The matrix weights are inversely proportional to the holding company-specific covariance matrices estimated at the OLS stage.

$$H_h = \{\sum_{i=1}^{F}[\Delta + \sigma_{ii}(X_i'X_i)^{-1}]^{-1}\}^{-1}[\Delta + \sigma_{hh}(X_h'X_h)^{-1}]^{-1}$$

Δ is estimated by:

$$\hat{\Delta} = \frac{\sum_{h=1}^{F} b_h b_b' - \frac{1}{F}\sum_{h=1}^{F} b_h \sum_{h=1}^{F} b_h'}{F-1}$$

3. The Swamy random coefficient vector, $\tilde{\beta}_h$ is a matrix weighted average of the mean coefficient vector of step (2) and the OLS estimators of step (1). That is:

$$\tilde{\beta}_h = (\Delta^{-1} + \sigma_{hh}^{-1} X_h' X_h)^{-1}(\sigma_{hh}^{-1} X_h' X_h b_h + \Delta^{-1}\hat{\beta})$$

Given the organizational difficulties of reporting on the vast number of parameter estimates that would be generated for the random coefficient model, pursuing this line of research was considered to be beyond the scope of the objectives for this dissertation.

5.4 Hypotheses Concerning Determinants of Pace of Transition to Equal Access

The explanatory variables that were discussed above fall into four broad categories. Firstly, there are variables concerning the nature of the telecommunications infrastructure. These are in the form of binary variables indicating types of local switches, as well as a proximity variable measuring the distance from the switch to the nearest AT&T point-of-presence. Secondly, there are variables that characterize the local economic milieu. Some of these are measured at the end-office level and others at the county level. A third set of variables characterize the firms that are making and implementing innovation strategies. Lastly, there are indicators of state regulatory environments. Inclusion of these variables in models of the duration to cut-over enable testing of the following hypotheses, all understood as factors promoting faster cut-over:

1. Newer vintage of switching system
2. Information intensity of employment structure
3. High international and interstate composition of telecommunications traffic flows
4. Agglomeration effects
5. Proximity to IEC point-of-presence
6. Economies of scope of larger firms
7. Regional Holding Companies (former Bell Operating Companies) relative to independents
8. Activist state regulation

TABLE 5.19: Independent variables used in regression analysis

End Office level		
variable	*SAS name*	*explanation*
A	C6N	Number of end offices in same city
A^*	LC6N	$\ln(A)$
D	ATT	Distance to POP
D^*	LATT	$\ln(D)$
K_1	SWTYPE1	dummy: electronic switch
K_2	SWTYPE2	dummy: remote switch
K_3	SWTYPE3	dummy: step-by-step switch
K_4	SWTYPE4	dummy: crossbar switch
R	REV	revenue
R^*	LREV	$\ln(R)$
Z^*	LSMSAEA	ln(mean days before Eq. Access in company/SMSA)
County level		
C_1	CNTY1	dummy: suburban
C_2	CNTY2	dummy: urban
$\dot{E}^*$	LGEMP	$\ln(employment_{1984-88}/employment_{1979-83})$
Regional Holding Company level		
H_1	HC1	dummy: BELL SOUTH
H_2	HC2	dummy: GTE
H_3	HC3	dummy: BELL ATLANTIC
H_4	HC4	dummy: NYNEX
H_5	HC5	dummy: AMERITECH
H_6	HC6	dummy: USWEST
H_7	HC7	dummy: SOUTHWESTERN BELL
H_8	HC8	dummy: PACIFIC TELESIS
H_9	HC9	dummy: CENTEL
H_{10}	HC10	dummy: CONTEL
SMSA level		
G_1	GROUP1	dummy: Nodal SMSAs (Noyelle-Stanback)
G_2	GROUP2	dummy: Specialized Services SMSAs (Noyelle-Stanback)
G_3	GROUP3	dummy: Production SMSAs (Noyelle-Stanback)
G_4	GROUP4	dummy: Consumer Oriented SMSAs (Noyelle-Stanback)
$Q(I)$	NI_E	location quotient: information emp. % (national benchmark)
$Q(M_1)$	N_BS	location quotient: intrastate % (national benchmark)
$Q(M_2)$	N_BUSOUT	location quotient: non-intrastate % (national benchmark)
$Q(R_B)$	N_BREV_	location quotient: business rev. % (national benchmark)
$Q(\tilde{I})$	ZI_E	location quotient: information emp. % (size group benchmark)
$Q(\tilde{M}_1)$	Z_BS	location quotient: intrastate % (size group benchmark)
$Q(\tilde{M}_2)$	Z_BUSOUT	location quotient: non-intrastate % (size group benchmark)
$Q(\tilde{R}_B)$	Z_BREV_	location quotient: business rev. % (size group benchmark)
S_2	SIZE2	dummy: size of SMSA group 2
S_3	SIZE3	dummy: size of SMSA group 3
S_4	SIZE4	dummy: size of SMSA group 4
S_5	SIZE5	dummy: size of SMSA group 5

5.5 Alternative Specifications

To summarize then, as listed in Table 5.19, the independent variables used in the regression analysis fall into four categories. These categories are distinguished according to the level of geographical aggregation at which they are defined, that is, the end-office, county, regional holding company, or SMSA levels. A fifth category allows for the inclusion of state dummies. The alternative equation specifications that were considered were selected from composites of the selected subset of variables chosen from among the following alternatives for each aggregation level:

- End Office level alternative specifications
  1. $K_1, \ldots, K_4$
  2. $A, D, R, K_1, \ldots, K_4$
  3. $A^*, D^*, R^*, K_1, \ldots, K_4$
  4. $K_1, \ldots, K_4, Z^*$
  5. $A, D, R, K_1, \ldots, K_4, Z^*$
  6. $A^*, D^*, R^*, K_1, \ldots, K_4, Z^*$
- County level alternative specifications
  1. None
  2. $\dot{E}^*$
  3. C_1, C_2
  4. $\dot{E}^*, C_1, C_2$
- Regional Holding Company level alternatives
  1. Seven dummies, $H_1, \ldots, H_7$
  2. Ten dummies, $H_1, \ldots, H_{10}$
  3. Intercept represents company (for separate regression runs by company)
- SMSA level alternative specifications
  1. None
  2. $S_2, \ldots, S_5$
  3. $Q(I), Q(M_2), Q(R_B)$
  4. $Q(\tilde{I}), Q(\tilde{M}_2), Q(\tilde{R}_B)$
  5. $S_2, \ldots, S_5, Q(I), Q(M_2), Q(R_B)$
  6. $S_2, \ldots, S_5, Q(\tilde{I}), Q(\tilde{M}_2), Q(\tilde{R}_B)$
  7. $G_1, \ldots, G_4$
  8. $G_1, \ldots, G_4, S_2, \ldots, S_5$
- State level alternatives
  1. No state dummies
  2. 47 dummies for the contiguous states. (Wyoming is not given an explicit dummy).

TABLE 5.20: Alternative regression specifications. Disaggregate dataset (9265 obs.)

method = pooled OLS					
	version of:				
Reference #	*Office*	*County*	*SMSA*	*Company*	*State*
1	3	2	5	1	1
2	3	2	6	1	1
3	3	2	6	2	1
4	3	2	8	1	1
5	3	3	1	2	2
6	3	4	1	1	1
7	6	1	1	2	2

The specifications formed by composites of these alternatives (i.e., 6 end office alternatives, 4 county level choices, 3 alternatives for number of company dummies, 8 alternatives considered among the SMSA-level variables, and inclusion or exclusion of state dummies) would imply 1,152 possible regression equations.

In addition to examining the sensitivity of results to the variables included, four alternative datasets were utilized. The first, most disaggregate and most complete dataset contained 9,265 observations comprised of data for all of the RBOCs and major independent companies, and with the dependent variable measured at the end office level of detail. The second dataset was a subset of the first, in which all of the independent companies, except GTE were deleted. The companies included in this second dataset, which contained 7,972 observations, are the only ones for which there were explicit legal requirements for Equal Access implementation. The other companies, of course were subject to market pressures to implement Equal Access. The third dataset, having 1,472 observations, is a more aggregate version of the first. Similarly, the fourth dataset, which contains 1,218 observations, is an aggregation of the second dataset. For both of these aggregate datasets, mean values for all of the variables included in the disaggregate counterparts were calculated for the level of aggregation defined by the intersection of type of switch (K_k), holding company (H_h), SMSA, and state. In addition to allowing investigation of the robustness of the analysis to aggregation (comparing results for the four datasets), it was also possible to examine the impact of adjusting for a simple form of heteroskedastic errors[19].

The 29 alternative analyses that were actually performed, varying variables included, level of aggregation and scope of the data are listed in Tables 5.20–5.23.

[19]When the number of observations contributing to grouped data is known, it is advisable to run a form of Weighted Least Squares in which the weights are the square root of the number of disaggregate observations that formed the group.

TABLE 5.21: Alternative regression specifications. Disaggregate dataset (7972 obs.)

method = pooled OLS					
	version of:				
Reference #	*Office*	*County*	*SMSA*	*Company*	*State*
8	2	1	3	1	1
9	2	1	4	1	1
10	3	2	2	1	1
11	3	2	3	1	1
12	3	2	4	1	1
13	3	2	5	1	1
14	3	2	6	1	1
15	3	2	7	1	1
16	3	2	8	1	1
17	6	2	1	1	1

TABLE 5.22: Alternative regression specifications. Aggregate dataset (1472 obs.)

method = pooled OLS					
	version of:				
Reference #	*Office*	*County*	*SMSA*	*Company*	*State*
18	3	1	1	2	2
19	3	3	1	2	2
method = pooled Weighted Least Squares					
20	3	1	1	2	2
21	3	3	1	2	2

TABLE 5.23: Alternative regression specifications. Aggregate dataset (1218 obs.)

method = pooled OLS					
	version of:				
Reference #	*Office*	*County*	*SMSA*	*Company*	*State*
22	3	2	5	1	1
23	3	2	6	1	1
24	3	2	8	1	1
25	3	4	1	1	1
method = pooled Weighted Least Squares					
26	3	2	5	1	1
27	3	2	6	1	1
28	3	2	8	1	1
29	3	4	1	1	1

TABLE 5.24: Summary statistics for alternative specifications

Reference #	Method	# of obs.	R^2	Adjusted R^2
1			0.4883	0.4871
2			0.4880	0.4868
3			0.4972	0.4958
4	OLS	9265	0.4858	0.4845
5			0.5223	0.5189
6			0.4815	0.4805
7			0.5497	0.5465
8			0.4668	0.4656
9			0.4654	0.4643
10			0.4904	0.4892
11			0.4950	0.4938
12			0.4937	0.4925
13			0.4958	0.4944
14	OLS	7972	0.4956	0.4942
15			0.4937	0.4925
16			0.4947	0.4933
17			0.5247	0.5238
18	OLS	1472	0.5197	0.4982
19			0.5210	0.4989
20	WLS	1472	0.6170	0.5999
21			0.6174	0.5997
22			0.4629	0.4530
23	OLS	1218	0.4634	0.4535
24			0.4605	0.4501
25			0.4568	0.4491
26			0.5831	0.5754
27	WLS	1218	0.5834	0.5757
28			0.5800	0.5720
29			0.5753	0.5693

5.6 Regression Results

As should be clear from the discussion on alternative specifications in the previous section, regression results from the following 6 contexts will be reported.

1. Pooled[20] OLS estimation using the disaggregate data set containing 9,265 observations.
2. Pooled OLS estimation using the smaller disaggregate data set containing 7,972 observations. This data set differs from the first in that the observations for the smaller independent holding companies have been dropped.
3. Pooled OLS estimation using the aggregate data set containing 1,472 observations (the counterpart of the 9,265 observation file).
4. Pooled Weighted Least Squares (WLS) estimation using the 1,472 observation data set.
5. Pooled OLS estimation using the aggregate dataset containing 1,218 observations (the counterpart of the 7,972 observation data set).
6. Pooled WLS using the 1,218 observation data set.

[20]Pooled estimation is being defined to be stacking of the submatrices of observations for the different regional holding companies, i.e., constraining the parameter estimates to have "national" values, rather than regionally–specific values.

TABLE 5.25: Paired Regressions: OLS versus WLS

Dataset	OLS ref. #	OLS adj. R^2	WLS ref. #	WLS adj. R^2
1472 obs.	18	.4982	20	.5999
	19	.4989	21	.5997
1218 obs.	22	.4530	26	.5754
	23	.4535	27	.5757
	24	.4501	28	.5717

5.6.1 Analysis of fit

Table 5.24 reports the R^2 and adjusted R^2 statistics for the OLS and WLS regressions. The alternative regression designs were selected to enable pairwise comparisons. The pairwise comparisons shown in the tables below, which contrast adjusted R^2 statistics, should also be used in evaluating reported coefficient estimates. Among the comparisons that can be made are the following:

- Table 5.25 relates identical models and datasets, estimated by OLS and WLS. When estimating a model using grouped data, if the different groups making up the dataset are based on a different number of underlying observations, the errors will be heteroskedastic. The variance of the disturbance term is no longer σ^2, but rather is σ^2/N_g, where N_g is the number of observations in the disaggregate dataset in the g^{th} subgroup. As the results in Table 5.25 confirm, solving the heteroskedasticity problem by transforming the original data by multiplying each variable by the $\sqrt{N_g}$ and then applying OLS on the transformed data, produces higher coefficients of determination (Berndt 1991, 12).

- Regression run #3 differs from #2 by the inclusion of three additional dummies for Pacific Telesis and the smaller independent holding companies (CENTEL and CONTEL). Table 5.26 shows that the adjusted R^2 increases from .4868 to .4958.

- Table 5.27 shows that from the standpoint of fit, there is essentially no difference among regression runs in the manner in which the location quotient variables are defined (using national benchmarks rather than SMSA size group benchmarks).

- Table 5.28 compares the fits for alternative specifications for classifying types of SMSAs. The left panel shows the results for the runs in which the three information economy location quotients (alone, or in combination with the size of SMSA dummies) are used to classify SMSAs. The right panel shows the fit for the runs in which the SMSAs are classified according to Noyelle-Stanback groups (alone, or in combination with size of SMSA dummies). The fit for the specifications using the location quotient variables is in each case higher than the Noyelle-Stanback specifications, but not by very much. A preference for the information-economy location variables over the Noyelle-Stanback dummies can therefore be justified more on the basis of their greater interpretability in the context of a telecommunications innovation, rather than on purely empirical grounds.

TABLE 5.26: Paired Regressions: 7 versus 10 company dummies

Dataset (# of obs.)	ref. #	adj. R^2	ref. #	adj. R^2
9265	2	.4868	3	.4958

TABLE 5.27: Paired Regressions: National versus Size Group Benchmarks

Dataset (# of obs.)	National SMSA specification	National ref. #	National adj. R^2	SMSA Size Group SMSA specification	SMSA Size Group ref. #	SMSA Size Group adj. R^2
Location Quotient Variables						
9265	5	1	.4871	6	2	.4868
7972	3	8	.4656	3	9	.4643
7972	3	11	.4938	3	12	.4925
7972	5	13	.4944	6	14	.4942
1218	5	22	.4530	6	23	.4535
1218	5	26	.5754	6	27	.5757

TABLE 5.28: Paired Regressions: Alternative specifications of SMSA types

Dataset (# of obs.)	Information Economy Loc. Quot. SMSA specification	Information Economy Loc. Quot. ref. #	Information Economy Loc. Quot. adj. R^2	Noyelle-Stanback dummies SMSA specification	Noyelle-Stanback dummies ref. #	Noyelle-Stanback dummies adj. R^2
Location Quotient Variables						
7972	3	11	.4938	7	15	.4925
7972	5	13	.4944	8	16	.4933
1218	5	22	.4530	8	24	.4501

TABLE 5.29: Regression results for specification # 4

Summary Statistics				
observations	R^2	adjusted R^2	F	σ
9265	.4972	.4958	356.460	.4583122

Parameter Estimates				
description	*variable*	*parameter*	*t-statistic*	*standardized estimates*
Intercept		7.61436988	70.013	0
Agglomeration	A^*	-0.09078760	-14.872	-0.15082471
Distance to POP	D^*	0.06019092	14.287	0.14097043
Revenue	R^*	-0.12300754	-30.467	-0.30084957
Electronic switch	K_1	-0.30929016	-22.129	-0.23869319
Remote switch	K_2	-0.49004246	-29.564	-0.27491563
Step-by-step switch	K_3	0.10980078	4.396	0.03725471
Crossbar switch	K_4	0.35256532	17.427	0.15582437
Employment growth	$\dot{E}^*$	-0.03900107	-3.768	-0.02881445
BELL SOUTH	H_1	-0.41726936	-19.838	-0.23255093
GTE	H_2	-0.13155518	-6.265	-0.07247973
BELL ATLANTIC	H_3	-0.48217715	-21.114	-0.23641186
NYNEX	H_4	-0.25563168	-10.919	-0.12460080
AMERITECH	H_5	-0.19869612	-8.618	-0.09355720
USWEST	H_6	-0.42721084	-17.982	-0.19984131
SOUTHWESTERN BELL	H_7	-0.40068367	-14.655	-0.15535137
PACIFIC TELESIS	H_8	-0.34847678	-12.700	-0.13162343
CENTEL	H_9	-0.14852741	-4.105	-0.03408908
CONTEL	H_{10}	-0.21014049	-6.578	-0.05744160
Information emp. l.q.	$Q(\tilde{I})$	-0.48098112	-4.621	-0.04668675
Non-intrastate % l.q.	$Q(\tilde{M}_2)$	-0.04678060	-1.941	-0.01965098
Bus. rev. % l.q.	$Q(\tilde{R}_B)$	-0.15053131	-5.193	-0.04778563
Size of SMSA group 2	$S2$	0.10336150	3.036	0.03478467
Size of SMSA group 3	$S3$	0.11747536	3.835	0.05387315
Size of SMSA group 4	$S4$	0.06365504	2.240	0.04125490
Size of SMSA group 5	$S5$	0.02085581	0.754	0.01586719

5.6.2 Analysis of parameter estimates

Table 5.29 reports a complete set of regression results for run #4. This model was somewhat arbitrarily chosen as a point-of-reference for discussion of all of the models. The results for the other models are presented in terms of standardized parameter estimates.[21] The last column of Table 5.29 lists standardized estimates for model #4. These coefficients are the estimates obtained when the all the variables in the model are standardized to zero mean and variance of one prior to estimation. The coefficient estimates for standardized variables can then be interpreted as the number of standard deviation changes in the dependent variable associated with a standard deviation change in the independent variable, holding all the other independent variables constant. With the exception of the last variable in the table (the dummy variable for the largest SMSAs), all of the estimates are significant and have the expected sign.

In the case of the dummy variables, the coefficients can be positive or negative. The prior expectation in the case of these variables is with respect to the relative ordering of the related set of dummies. For instance, the remote and electronic switches should have substantially faster cutover times to Equal Access than the step-by-step and crossbar switches. The four dummies could all be positive, all be negative, or, as in the case of this model's results, be of mixed signs. The same holds for the company dummies and the size of SMSA dummies.

In the case of the company dummies, it is hypothesized that the larger companies, based on economies of scale and economies of scope, will tend to have faster implementation schedules. For the same reason, the larger metropolitan areas are expected to have more negative (or less positive) coefficients than the smaller size groups.

To ease comparisons among models, the following set of tables, show for each table, the standardized coefficient estimates for all of the pooled OLS and WLS runs. The separate tables show results for related sets of variables.

For example, Table 5.31 reports the parameter estimates for the continuous end-office level variables, for the logarithmic version of these variables. The levels version are reported in Table 5.30. All of the different specifications show a rather uniform result that the revenue variable tends to be more than double the magnitude of the other two variables. The relatively large magnitude of all three variables provide evidence that the implementation schedules reflect a high degree of "micro-management". These results suggest, for instance, that within a given metropolitan area and a given switching technology, there is an ordering favoring: the larger cities making up the metropolitan area (many end-offices per city—variable A or $ln(A)$); end-offices located close to an AT&T point-of-presence (the shorter the distance, the lower the value of D); more profitable end-offices[22]. Inclusion of the spatial autoregressive variable (Z^*), a particularly strong variable, does not dramatically alter the relationship among the other variables.

The standardized coefficient estimates for the switch-type dummy variables are displayed in Table 5.32. The most common ranking in terms of time to cutover of the four switch-type among the various runs is remote (K_2), electronic (K_1), crossbar

[21] These are sometimes refered to in the literature as "beta coefficients" (Kennedy 1992, 368).

[22] Recall that variable R is AT&T telecommunications services revenues at the end-office level. This is assumed to highly correlated with the level of local operating company revenues and other long distance carriers' revenues, as well as with profitability at the end-office level. Unfortunately, data was not available to directly verify this hypothesis. The strength of this variable provides secondary evidence in support of the hypothesis.

(K_4), and step-by-step (K_3). Since the remote switches are introduced explicitly to accomodate Equal Access this ranking was expected.

Table 5.33 shows results for the county-level variables. Most of the runs suggest that, holding other things constant, urban counties (C_2) implemented Equal Access more rapidly than suburban (C_1) and rural (the excluded category) counties. Local economic growth, as reflected by the employment growth variable, although consistently significant, has a much weaker effect than the end-office level variables.

The standardized coefficients for the regional holding company dummy variables are presented in Tables 5.34 and 5.36. The relative rankings for these impacts are more sensitive to the specifications than most of the other variables. One expected and rather unambiguous result is that the smaller independent companies (CENTEL, CONTEL, and the other companies not given an explicit dummy) have slower implementation schedules than most of the RBOCs. Bell South, the largest of the RBOCs in terms of number of end-offices, with a few exceptions, shows the fastest implementation. NYNEX shows slower than expected implementation.

The five regression models that considered the Noyelle and Stanback schema for classifying SMSAs are shown in Table 5.37. Although they did not explicitly address the Equal Access issue—in fact the book was published before the issue existed—their arguments are consistent with the reported results that the nodal centers have substantially faster cutover.

The size of SMSA effect, reported in Table 5.38, is the only result counter to that hypothesized. The smaller SMSAs often show faster cutovers (small positive coefficients). A number of the regression runs do show the largest SMSA group having the fastest cutover (small positive coefficients or large negative values), so the results are not definitive. There clearly is not robust evidence of a monotonic relationship between metropolitan size and speed of adoption of Equal Access capability.

Table 5.39 reports the standardized coefficient estimates for the location quotient variables. In most of the regression runs, the information employment effect is the strongest of the three variables. The business revenue proportion effect tends to be the weakest of the three. All three effects are nearly always significant. These results support the hypothesis that there is substantially slower rate of adoption of this innovation in the "periphery" of the information economy.

The results for state dummy variables are displayed in Tables 5.40, 5.41, and 5.42. The state effect is hypothesized to be related to the degree of regulatory oversight of the Equal Access process at the state level. Explicit research on this issue was not undertaken. The econometric results show a consistent strong state effect for Massachusetts, New York, Nevada, Pennsylvania, Texas, Vermont, and Wisconsin.

All of the variables in the disaggregate models (specifications #1–#17) were highly significant, with the exception of some of the company dummy variables in some of the runs/footnoteGTE in runs #1, #2, #4, #6, and #7; CENTEL in runs #5, #7; and Southwestern Bell in run #10., the non-intrastate calling location quotient in several models[23], and some of the state dummy variables. For the models estimated using the aggregate datasets (runs, in which much of variation between observations has been elimated by the aggregation process, unsurprisingly, more of the variables designed to capture differences between companies and types of smsa (specifications #18–#29) a larger number of variables loose their statistical significance. The appendix, which lists all of the regression models sorted by the size of the standardized estimates, shows that all insignificant variables (low t-statistics) have low standardized parameter estimates.

[23]runs #8, #9, #12, and #13.

In summary, the most important empirical results of this study are that by far the most important variables explaining the pace of Equal Access implementation are those capturing the variation within regional holding company service territories and within the same type of metropolitan area. The degree of centrality of a metropolitan area in the information economy accounts for a much smaller proportion of the total variation, but tends to be a statistically significant effect.

TABLE 5.30: Standardized Coefficients: End-Office Level Variables

Reference #	Method	*A*	*D*	*R*
8	OLS	-0.050	0.121	-0.325
9	OLS	-0.057	0.122	-0.331

TABLE 5.31: Standardized Coef.: End-Office Variables (logaritmic version)

Reference #	Method	A^*	D^*	R^*	Z^*
1	OLS	-0.165	0.128	-0.312	.
2	OLS	-0.165	0.128	-0.313	.
3	OLS	-0.151	0.141	-0.301	.
4	OLS	-0.165	0.132	-0.308	.
5	OLS	-0.160	0.160	-0.320	.
6	OLS	-0.179	0.132	-0.320	.
7	OLS	-0.120	0.128	-0.291	0.251
10	OLS	-0.157	0.163	-0.334	.
11	OLS	-0.138	0.148	-0.319	.
12	OLS	-0.146	0.145	-0.323	.
13	OLS	-0.136	0.148	-0.319	.
14	OLS	-0.136	0.149	-0.319	.
15	OLS	-0.138	0.154	-0.318	.
16	OLS	-0.139	0.150	-0.317	.
17	OLS	-0.111	0.126	-0.293	0.238
18	OLS	-0.133	0.149	-0.365	.
19	OLS	-0.134	0.163	-0.369	.
20	WLS	-0.150	0.159	-0.390	.
21	WLS	-0.151	0.170	-0.391	.
22	OLS	-0.114	0.116	-0.344	.
23	OLS	-0.115	0.117	-0.345	.
24	OLS	-0.124	0.120	-0.346	.
25	OLS	-0.133	0.109	-0.353	.
26	WLS	-0.127	0.106	-0.370	.
27	WLS	-0.127	0.108	-0.370	.
28	WLS	-0.133	0.113	-0.371	.
29	WLS	-0.159	0.108	-0.384	.

TABLE 5.32: Standardized Coefficients: Switch Type Dummy Variables

Reference #	Method	K_1	K_2	K_3	K_4
1	OLS	-0.219	-0.266	0.041	0.158
2	OLS	-0.220	-0.267	0.041	0.157
3	OLS	-0.239	-0.275	0.037	0.156
4	OLS	-0.219	-0.263	0.042	0.157
5	OLS	-0.242	-0.281	0.035	0.147
6	OLS	-0.225	-0.268	0.044	0.155
7	OLS	-0.216	-0.256	0.032	0.153
8	OLS	-0.314	-0.273	0.032	0.105
9	OLS	-0.316	-0.273	0.033	0.103
10	OLS	-0.267	-0.305	0.037	0.155
11	OLS	-0.266	-0.309	0.029	0.153
12	OLS	-0.267	-0.309	0.031	0.152
13	OLS	-0.265	-0.307	0.030	0.154
14	OLS	-0.266	-0.308	0.030	0.154
15	OLS	-0.261	-0.304	0.035	0.157
16	OLS	-0.260	-0.303	0.036	0.158
17	OLS	-0.232	-0.278	0.030	0.158
18	OLS	-0.163	-0.325	0.095	0.248
19	OLS	-0.162	-0.325	0.097	0.251
20	WLS	-0.208	-0.354	0.072	0.229
21	WLS	-0.207	-0.354	0.073	0.230
22	OLS	-0.224	-0.341	0.114	0.260
23	OLS	-0.223	-0.341	0.114	0.260
24	OLS	-0.221	-0.338	0.118	0.264
25	OLS	-0.217	-0.341	0.117	0.261
26	WLS	-0.274	-0.371	0.082	0.238
27	WLS	-0.273	-0.371	0.082	0.238
28	WLS	-0.269	-0.366	0.088	0.242
29	WLS	-0.265	-0.371	0.089	0.243

TABLE 5.33: Standardized Coefficients: County-Level Variables

Reference #	Method	C_1	C_2	$\dot{E}^*$
1	OLS	.	.	-0.031
2	OLS	.	.	-0.031
3	OLS	.	.	-0.029
4	OLS	.	.	-0.030
5	OLS	-0.028	-0.032	.
6	OLS	-0.046	-0.056	-0.033
10	OLS	.	.	-0.034
11	OLS	.	.	-0.029
12	OLS	.	.	-0.030
13	OLS	.	.	-0.028
14	OLS	.	.	-0.028
15	OLS	.	.	-0.031
16	OLS	.	.	-0.029
17	OLS	.	.	-0.007
39	OLS	.	.	-0.019
19	OLS	0.061	0.072	.
21	WLS	0.015	0.033	.
22	OLS	.	.	-0.028
23	OLS	.	.	-0.028
24	OLS	.	.	-0.036
25	OLS	0.024	-0.012	-0.037
26	WLS	.	.	-0.031
27	WLS	.	.	-0.030
28	WLS	.	.	-0.036
29	WLS	-0.009	-0.034	-0.039

TABLE 5.34: Standardized Coefficients: 7 Regional Holding Company Dummy Variables (OLS)

Reference #	BELL SOUTH	GTE	BELL ATLANTIC	NYNEX	AMERITECH	USWEST	S.W. BELL
1	-0.153	0.012	-0.164	-0.056	-0.021	-0.137	-0.092
2	-0.151	0.013	-0.163	-0.053	0.020	-0.134	-0.091
4	-0.151	0.012	-0.178	-0.060	-0.030	-0.144	-0.101
6	-0.153	0.013	-0.185	-0.062	-0.027	-0.136	-0.095
8	-0.080	0.100	-0.074	0.038	0.044	-0.067	-0.063
9	-0.081	0.098	-0.076	0.039	0.044	-0.064	-0.063
10	-0.042	0.136	-0.078	0.033	0.084	-0.053	-0.026
11	-0.049	0.126	-0.060	0.050	0.082	-0.039	-0.022
12	-0.051	0.125	-0.064	0.049	0.081	-0.036	-0.022
13	-0.050	0.124	-0.063	0.045	0.080	-0.044	-0.024
14	-0.045	0.127	-0.060	0.051	0.084	-0.040	-0.022
15	-0.047	0.135	-0.072	0.039	0.083	-0.051	-0.027
16	-0.047	0.133	-0.073	0.036	0.083	-0.054	-0.029
17	-0.031	0.108	-0.023	0.014	0.086	-0.034	0.001
22	0.003	0.300	0.025	0.094	0.160	0.069	0.010
23	0.006	0.302	0.028	0.098	0.162	0.074	0.012
24	-0.012	0.288	-0.008	0.066	0.146	0.039	-0.001
25	-0.027	0.274	-0.016	0.059	0.142	0.023	-0.010

TABLE 5.35: Standardized Coefficients: 10 Regional Holding Company Dummy Variables (OLS)

Reference #	BELL SOUTH	GTE	BELL ATLANTIC	NYNEX	AMERITECH	USWEST	S.W. BELL	PACIFIC TELESIS	CENTEL	CONTEL
3	-0.233	-0.072	-0.236	-0.125	-0.094	-0.200	-0.155	-0.132	-0.034	-0.057
5	-0.311	-0.053	-0.268	0.053	-0.083	-0.235	-0.098	-0.114	-0.007	-0.059
7	-0.189	-0.017	-0.144	0.056	-0.021	-0.137	-0.033	-0.093	0.001	-0.059
18	-0.390	-0.085	-0.305	-0.003	-0.113	-0.282	-0.186	-0.164	-0.032	-0.052
19	-0.395	-0.087	-0.314	-0.005	-0.113	-0.287	-0.188	-0.165	-0.030	-0.052

TABLE 5.36: Standardized Coefficients: Regional Holding Company Dummy Variables (WLS)

Reference #	BELL SOUTH	GTE	BELL ATLANTIC	NYNEX	AMERITECH	USWEST	S.W. BELL
20	-0.390	-0.069	-0.327	0.038	-0.099	-0.288	-0.139
21	-0.391	-0.070	-0.329	0.037	-0.099	-0.289	-0.140
26	-0.035	0.230	-0.027	0.079	0.129	0.008	-0.010
27	-0.031	0.233	-0.023	0.084	0.131	0.013	-0.008
28	-0.045	0.228	-0.054	0.054	0.121	-0.020	-0.020
29	-0.055	0.219	-0.068	0.046	0.115	-0.027	-0.019

TABLE 5.37: Standardized Coefficients: Noyelle-Stanback Groups Dummy Variables

Reference #	Method	G_1	G_2	G_3	G_4
4	OLS	-0.079	-0.030	-0.031	-0.047
15	OLS	-0.078	-0.034	-0.015	-0.032
16	OLS	-0.082	-0.040	-0.019	-0.035
24	OLS	-0.060	0.025	0.004	-0.010
28	WLS	-0.086	-0.019	-0.014	-0.027

TABLE 5.38: Standardized Coefficients: Size of SMSA Dummy Variables

Reference #	Method	S_2	S_3	S_4	S_5
1	OLS	0.043	0.060	0.063	0.063
2	OLS	0.041	0.055	0.051	0.030
3	OLS	0.035	0.054	0.041	0.016
4	OLS	0.035	0.056	0.075	0.074
10	OLS	0.031	0.046	0.059	0.050
13	OLS	0.030	0.046	0.058	0.052
14	OLS	0.031	0.047	0.050	0.020
16	OLS	0.025	0.046	0.075	0.074
22	OLS	-0.015	0.005	-0.010	-0.020
23	OLS	-0.008	0.012	-0.014	-0.047
24	OLS	-0.013	0.008	-0.011	-0.003
26	WLS	0.010	0.023	0.014	0.010
27	WLS	0.014	0.027	0.007	-0.026
28	WLS	0.007	0.026	0.030	0.038

TABLE 5.39: Standardized Coefficients: Location Quotient Variables

Reference #	Method	$Q(I)$	$Q(M_2)$	$Q(R_B)$	$Q(\tilde{I})$	$Q(\tilde{M}_2)$	$Q(\tilde{R}_B)$
1	OLS	-0.055	0.027	-0.074	.	.	.
2	OLS	.	.	.	-0.056	0.021	-0.071
3	OLS	.	.	.	-0.047	-0.020	-0.048
8	OLS	-0.103	-0.014	-0.048	.	.	.
9	OLS	.	.	.	-0.101	-0.011	-0.036
11	OLS	-0.051	-0.019	-0.048	.	.	.
12	OLS	.	.	.	-0.052	-0.015	-0.034
13	OLS	-0.053	-0.015	-0.048	.	.	.
14	OLS	.	.	.	-0.054	-0.023	-0.044
22	OLS	-0.047	-0.059	-0.022	.	.	.
23	OLS	.	.	.	-0.048	-0.065	-0.021
26	WLS	-0.062	-0.046	-0.040	.	.	.
27	WLS	.	.	.	-0.063	-0.054	-0.037

TABLE 5.40: Standardized Coefficients: State dummies (OLS) (fast)

	reference number:							
state	1	8	11	13	36	37	38	40
AR	-0.051	-0.051	-0.056	-0.043	-0.071	-0.072	-0.074	-0.075
CA	-0.049	-0.046	-0.063	0.002	-0.060	-0.076	-0.081	-0.084
CO	0.005	-0.011	-0.004	-0.006	-0.039	-0.044	-0.041	-0.045
DE	-0.048	-0.038	-0.039	-0.016	-0.058	-0.043	-0.044	-0.040
GA	-0.018	-0.008	-0.011	-0.005	-0.028	-0.020	-0.019	-0.017
IA	-0.012	-0.011	-0.018	-0.011	-0.028	-0.045	-0.045	-0.044
ID	-0.009	-0.020	-0.018	-0.027	-0.055	-0.059	-0.059	-0.058
IL	-0.018	-0.023	-0.034	-0.009	-0.045	-0.056	-0.054	-0.059
IN	-0.025	-0.002	-0.022	0.009	-0.066	-0.049	-0.055	-0.048
KS	-0.019	-0.019	-0.022	-0.018	-0.023	-0.029	-0.029	-0.031
KY	-0.026	-0.005	-0.015	-0.006	-0.080	-0.059	-0.064	-0.056
MA	-0.128	-0.124	-0.124	-0.088	-0.150	-0.122	-0.118	-0.124
ME	-0.075	-0.059	-0.061	-0.054	-0.096	-0.069	-0.068	-0.069
MI	-0.030	-0.018	-0.030	-0.010	-0.052	-0.019	-0.021	-0.021
MO	-0.032	-0.042	-0.044	-0.039	-0.065	-0.079	-0.078	-0.081
NC	-0.076	-0.030	-0.051	-0.010	-0.096	-0.056	-0.065	-0.051
NH	-0.074	-0.068	-0.068	-0.052	-0.121	-0.099	-0.097	-0.102
NM	-0.015	-0.010	-0.007	-0.006	-0.054	-0.045	-0.042	-0.048
NV	-0.090	-0.092	-0.091	-0.062	-0.142	-0.140	-0.139	-0.141
NY	-0.177	-0.161	-0.178	-0.115	-0.201	-0.168	-0.170	-0.168
OH	-0.073	-0.050	-0.069	-0.022	-0.108	-0.101	-0.105	-0.105
OK	-0.038	-0.037	-0.039	-0.026	-0.068	-0.065	-0.063	-0.068
OR	-0.014	-0.016	-0.021	-0.011	-0.039	-0.040	-0.042	-0.041
PA	-0.091	-0.068	-0.078	-0.033	-0.119	-0.097	-0.102	-0.095
RI	-0.049	-0.046	-0.046	-0.028	-0.074	-0.062	-0.060	-0.064
SC	-0.023	0.001	-0.010	0.003	-0.050	-0.025	-0.033	-0.025
TX	-0.090	-0.083	-0.095	-0.043	-0.092	-0.100	-0.099	-0.105
UT	-0.014	-0.027	-0.021	-0.017	-0.035	-0.046	-0.043	-0.047
VA	-0.055	-0.015	-0.031	0.009	-0.126	-0.029	-0.037	-0.016
VT	-0.089	-0.084	-0.083	-0.062	-0.091	-0.073	-0.072	-0.066
WA	-0.025	-0.023	-0.031	-0.011	-0.048	-0.049	-0.053	-0.050
WI	-0.092	-0.082	-0.092	-0.048	-0.124	-0.117	-0.120	-0.119

TABLE 5.41: Standardized Coefficients: State dummies (OLS) (slow)

	reference number:							
state	1	8	11	13	36	37	38	40
AL	-0.009	0.013	0.003	0.009	-0.036	-0.017	-0.023	-0.015
AZ	0.008	0.007	0.006	0.014	-0.020	-0.013	-0.014	-0.014
CT	0.021	0.019	0.025	0.029	-0.005	-0.006	-0.003	-0.009
FL	-0.006	0.010	-0.006	0.038	0.013	0.012	0.004	0.012
LA	0.025	0.049	0.037	0.024	0.005	0.028	0.025	0.030
MD	0.016	0.022	0.017	0.007	0.019	0.033	0.032	0.039
MS	0.009	0.024	0.017	0.001	-0.034	-0.025	-0.026	-0.024
MT	0.004	-0.006	-0.004	-0.006	-0.025	-0.037	-0.035	-0.035
ND	0.025	0.016	0.015	-0.003	0.001	-0.017	-0.018	-0.015
NE	0.020	0.017	0.009	0.007	-0.001	-0.007	-0.013	-0.006
NJ	0.042	0.011	0.014	0.016	-0.003	-0.012	-0.009	-0.012
SD	0.038	0.031	0.031	0.012	0.057	0.046	0.044	0.048
TN	-0.008	0.026	0.012	0.016	-0.031	-0.010	-0.016	-0.007
WV	0.019	0.022	0.022	0.003	-0.005	0.018	0.019	0.025

TABLE 5.42: Standardized Coefficients: State dummies (WLS)

	reference number:			
state	41	42	43	44
AL	-0.026	-0.004	-0.121	-0.004
AR	-0.075	-0.082	-0.014	-0.083
AZ	-0.007	-0.006	-0.023	-0.007
CA	-0.052	-0.072	-0.074	-0.077
CO	-0.020	-0.036	-0.031	-0.036
CT	0.007	0.007	0.012	0.006
DE	-0.070	-0.051	-0.053	-0.050
FL	0.013	0.014	-0.002	0.016
GA	-0.026	-0.021	-0.022	-0.019
IA	-0.022	-0.037	-0.040	-0.036
ID	-0.044	-0.054	-0.053	-0.054
IL	-0.037	-0.056	-0.060	-0.057
IN	-0.056	-0.042	-0.055	-0.041
KS	-0.030	-0.038	-0.039	-0.038
KY	-0.069	-0.049	-0.058	-0.047
LA	0.012	0.036	0.029	0.037
MA	-0.159	-0.144	-0.138	-0.145
MD	0.013	0.024	0.021	0.027
ME	-0.097	-0.075	-0.074	-0.074
MI	-0.033	-0.028	-0.034	-0.029
MO	-0.060	-0.082	-0.080	-0.011
MS	-0.026	-0.013	-0.017	-0.011
MT	-0.009	-0.024	-0.022	-0.023
NC	-0.089	-0.045	-0.061	-0.044
ND	0.013	-0.006	-0.007	-0.006
NE	0.014	0.002	-0.006	0.003
NH	-0.117	-0.105	-0.101	-0.105
NJ	0.038	0.003	0.007	0.005
NM	-0.044	-0.036	-0.032	-0.037
NV	-0.136	-0.138	-0.138	-0.138
NY	-0.218	-0.195	-0.201	-0.195
OH	-0.103	-0.096	-0.107	-0.096
OK	-0.066	-0.067	-0.065	-0.067
OR	-0.033	-0.040	-0.043	-0.040
PA	-0.125	-0.101	-0.110	-0.099
RI	-0.073	-0.068	-0.065	-0.068
SC	-0.042	-0.016	-0.027	-0.015
SD	0.050	0.037	0.035	0.038
TN	-0.027	0.002	-0.008	0.003
TX	-0.115	-0.121	-0.124	-0.123
UT	-0.030	-0.046	-0.040	-0.046
VA	-0.070	-0.027	-0.042	-0.022
VT	-0.109	-0.094	-0.093	-0.092
WA	-0.043	-0.048	-0.055	-0.048
WI	-0.124	-0.120	-0.125	-0.121
WV	0.004	0.020	0.020	0.023

The more important contributions, findings, and implications of this thesis are summarized below.

Methodological Contributions

The analysis of an innovation diffusion process within the U.S. telecommunications sector was approached within the conceptual framework of the information mode of development introduced by Castells. The origins of the new centrality of information processing can be traced to socioeconomic developments in the spheres of production, consumption, and state activity: the information flows linked to the ascendancy of the large corporation as the dominant organizational structure for production and management, with its corresponding needs to coordinate hierarchical and dispersed operations; the growing knowledge intensity of production processes; the information gathering systems utilized to stimulate consumption by means of systematically targeted marketing; and the network of information flows controlled and manipulated by bureaucratic state apparatuses.

Even in academic discourse there is a great deal of "hype" concerning the new communications technologies. Within communications networks, all places are *not* equivalent. Spatial barriers are only overcome to the extent to which all nodes of the network are equally accessible. Technical change in telecommunications does not occur simultaneously at all points of the network; it is a spatially differentiated innovation process, having a structure that is readily identifiable by econometric methods.

Technological diffusion is the term used to describe the spread of new technologies over time. Paul Krugman, given the John Bates Clark Medal by the American Economics Assocciation in 1991, has urged the profession to take economic geography–"that branch of economics that worries about where things happen in relation to one another' (Krugman 1991, 1)"–more seriously. In this study, the spatial aspects of the diffusion were explicitly incorporated into the analysis. The econometric framework adopted the more modern approach of directly modelling the duration of time before the adoption of the innovation, rather than more traditional approach based on modeling the proportion of adoptors at various points in time.

The long-term evolution of the U.S. telecommunications sector was traced in order to provide the necessary historical context for understanding the innovation diffusion process that was analyzed. Two aspects of the changing regulatory and market structures were emphasized. First, changing ideologies revolving around the form that the industry should take, played a more dominant role than technological change. Deregulatory fervor prompted many of the policy decisions taken at critical points in the evolutionary process. Second, the various policy changes had cumulative impacts. Decisions taken at one stage created or increased forces that would require later resolution. The changing regulatory environment and conditions of competition in the telecommunications sector has clearly demonstrated the forms by which markets are socially constructed.

Another area of investigation important for contextualizing the Equal Access process was the trajectory of technological change in telecommunications switching equipment. As Rosenberg (1994) has stressed, the telecommunications industry has a number of unique features important for understanding its rate and direction of technical change. These are: the importance of path dependence, i.e., that given that capital in telecommunications is unusually long-lived, early investment decisions can be locked-in for long periods[24] ; the complicated interdependencies of the components of the network, referred to as "systemness" or network externalities, in which innovations are adopted only when it is economically feasible to integrate them within a network system; the extraordinary role of research and development; and the impact of government policy on industry structure and the coordination of standardization. Switching systems have two essential elements, namely the switching network, and the control mechanism. The former consists of the individual switching devices used to establish communication paths. The latter governs the intelligence to operate the appropriate switching devices at the required time. The control function evolved from the use of relays and other electromechanical devices to the current system of "stored-program control", whereby new features can be introduced through changes in software rather than changes in hardware.

Findings

The empirical analysis of Equal Access demonstrated the relative influence of the installed configuration of switching equipment of various vintages in explaining the pattern of innovation diffusion. As expected, the econometric results showed that the remote and electronic switches displayed substantially faster cut-over times to Equal Access than the step-by-step and crossbar switches.

The most important variables explaining the pace of Equal Access implementation were shown to be those capturing the variation within regional holding company service territories and within the same type of metropolitan area. Variables designed to capture the degree of centrality of a metropolitan area in the information economy, although accounting for a much smaller porportion of the total variation, clearly demonstrate the existence of a core and a periphery for this telecommunications process.

This study has shown that it is possible to supplement traditional operational measures of the "information economy" based on the "information" content of various occupations by branches of employment by more direct measures based on the composition of telecommunications flows. The innovation process under study was shown to occur more rapidly in those areas whose composition of telecommunications flows was more "globally oriented" (i.e., a higher composition of international and interstate calling relative to intrastate) and the greater the business use (relative to residential use).

It is important to point out that this study cannot be use to confirm whether or not technological change in the telecommunications industry is tending to lead to a more polarized, or more uneven form of development, in which innovation patterns, through a process of cummulative causation would tend to be reproduced. Evidence for the polarization hypothesis, or counter evidence in support of a technological convergence hypothesis would require data on more than one innovation process (i.e., multiple observations for the same locations at different points in time). This study, by shedding light on one innovation process, has layed the groundwork for a more dynamic analysis.

[24] Rosenberg likened the concept of path dependence to a "mountain climber who takes the wrong route of descent from a peak and finds himself above a sheer cliff with no way to proceed further." Ironically, I had precisely this experience the day before reading Rosenberg's article.

Implications

This study pointed out that the Divestiture agreement created a system in which local exchange carriers and inter-exchange carriers, the principal actors of the telecommunications services industry, have opposing interests and regional development strategies. An agglomerative form of economic development is more favorable to the companies whose business is limited by regulation to the intra-LATA market. In contrast, inter-exchange carriers should seek to promote more decentralized territoral configurations and cross-LATA patterns of commuting.

The speed with which the myriad of technical and administrative problems connected with the divesture of the Bell Operating Companies from AT&T was accomplished, the transformation to nearly universal "Equal Access" within less than a decade, and other conversion processes in the telecommunications sector, have demonstrated the capacity of the U.S. economy to plan and successfully execute complex structural metamorphoses.

This thesis has relevance to the analysis of other spatially oriented diffusion processes in the U.S. context, but also to directly comparable processes taking place in other countries. This concluding chapter was written from the vantage point of another culture at a different level of economic development and spatially far from the United States. In spite of the impressive developments in the means of communications as reflected in such anecdotes as the ability from Chile to communicate by telephone with Professor Vietorisz in New York with a sound quality not perceptibly different than if I were calling from the same city, or the ability to see from this somewhat remote corner of the world a satellite transmission of a MacNeil-Lehrer Report interview with Professor Gordon, this thesis has shown that the transformations associated with the "information economy" have not completely annihilated space by time.

Appendix A

Appendix: Regression Results by Specification

[1]

[1] The tables are sorted in ascending order by the absolute value of the standardized parameter estimates. To economize on space, results for state dummy variables are not included in the tables.

TABLE A.1: Regression results for specification # 1

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	9265	23	0.4883	0.4871	400.924

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	7.481	69.701	0.000
Agglomeration	A^*	LC6N	-0.099	-16.199	-0.165
Distance to POP	D^*	LATT	0.055	12.942	0.128
Electronic switch	K_1	SWTYPE1	-0.284	-20.592	-0.219
Remote switch	K_2	SWTYPE2	-0.475	-28.704	-0.266
Step-by-step switch	K_3	SWTYPE3	0.122	4.872	0.041
Crossbar switch	K_4	SWTYPE4	0.357	17.567	0.158
Revenue	R^*	LREV	-0.128	-31.659	-0.312
Employment growth	$\dot{E}^*$	LGEMP	-0.043	-4.061	-0.031
BELL SOUTH	h_1	HC1	-0.275	-15.959	-0.153
GTE	h_2	HC2	0.022	1.329	0.012
BELL ATLANTIC	h_3	HC3	-0.335	-17.238	-0.164
NYNEX	h_4	HC4	-0.116	-5.753	-0.056
AMERITECH	h_5	HC5	-0.044	-2.275	-0.021
USWEST	h_6	HC6	-0.292	-14.126	-0.137
SOUTHWESTERN BELL	h_7	HC7	-0.236	-9.830	-0.092
Information emp. l.q.	$Q(I)$	NI_E	-0.581	-5.470	-0.055
Non-intrastate % l.q.	$Q(M_2)$	N_BUSOUT	0.070	2.906	0.027
Bus. rev % l.q.	$Q(R_B)$	N_BREV_	-0.244	-8.235	-0.074
Size of SMSA group 2	$S2$	SIZE2	0.126	3.673	0.043
Size of SMSA group 3	$S3$	SIZE3	0.131	4.231	0.060
Size of SMSA group 4	$S4$	SIZE4	0.097	3.397	0.063
Size of SMSA group 5	$S5$	SIZE5	0.083	3.010	0.063

TABLE A.2: Regression results for specification # 2

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	9265	23	0.4880	0.4868	400.4180

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	7.511	69.070	0.000
Agglomeration	A^*	LC6N	-0.100	-16.228	-0.165
Distance to POP	D^*	LATT	0.055	12.958	0.128
Electronic switch	K_1	SWTYPE1	-0.285	-20.642	-0.220
Remote switch	K_2	SWTYPE2	-0.475	-28.725	-0.267
Step-by-step switch	K_3	SWTYPE3	0.121	4.828	0.041
Crossbar switch	K_4	SWTYPE4	0.356	17.519	0.157
Revenue	R^*	LREV	-0.128	-31.708	-0.313
Employment growth	$\dot{E}^*$	LGEMP	-0.042	-4.031	-0.031
BELL SOUTH	h_1	HC1	-0.270	-15.718	-0.151
GTE	h_2	HC2	0.023	1.365	0.013
BELL ATLANTIC	h_3	HC3	-0.332	-17.071	-0.163
NYNEX	h_4	HC4	-0.109	-5.417	-0.053
AMERITECH	h_5	HC5	-0.043	-2.206	0.020
USWEST	h_6	HC6	-0.287	-13.860	-0.134
SOUTHWESTERN BELL	h_7	HC7	-0.235	-9.765	-0.091
Information emp. l.q.	$Q(\tilde{I})$	ZI_E	-0.579	-5.551	-0.056
Non-intrastate % l.q.	$Q(\tilde{M}_2)$	Z_BUSOUT	0.049	2.159	0.021
Bus. rev % l.q.	$Q(\tilde{R}_B)$	Z_BREV_	-0.225	-7.990	-0.071
Size of SMSA group 2	$S2$	SIZE2	0.123	3.574	0.041
Size of SMSA group 3	$S3$	SIZE3	0.120	3.882	0.055
Size of SMSA group 4	$S4$	SIZE4	0.079	2.769	0.051
Size of SMSA group 5	$S5$	SIZE5	0.039	1.416	0.030

TABLE A.3: Regression results for specification # 3

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	9265	26	0.4972	0.4958	365.460

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	7.614	70.013	0.000
Agglomeration	A^*	LC6N	-0.091	-14.872	-0.151
Distance to POP	D^*	LATT	0.060	14.287	0.141
Electronic switch	K_1	SWTYPE1	-0.309	-22.129	-0.239
Remote switch	K_2	SWTYPE2	-0.490	-29.564	-0.275
Step-by-step switch	K_3	SWTYPE3	0.110	4.396	0.037
Crossbar switch	K_4	SWTYPE4	0.353	17.427	0.156
Revenue	R^*	LREV	-0.123	-30.467	-0.301
Employment growth	$\dot{E}^*$	LGEMP	-0.039	-3.768	-0.029
BELL SOUTH	h_1	HC1	-0.417	-19.838	-0.233
GTE	h_2	HC2	-0.132	-6.265	-0.072
BELL ATLANTIC	h_3	HC3	-0.482	-21.114	-0.236
NYNEX	h_4	HC4	-0.256	-10.919	-0.125
AMERITECH	h_5	HC5	-0.199	-8.618	-0.094
USWEST	h_6	HC6	-0.427	-17.982	-0.200
SOUTHWESTERN BELL	h_7	HC7	-0.401	-14.655	-0.155
PACIFIC TELESIS	h_8	HC8	-0.348	-12.700	-0.132
CENTEL	h_9	HC9	-0.149	-4.105	-0.034
CONTEL	h_{10}	HC10	-0.210	-6.578	-0.057
Information emp. l.q.	$Q(\tilde{I})$	ZI_E	-0.481	-4.621	-0.047
Non-intrastate % l.q.	$Q(\tilde{M}_2)$	Z_BUSOUT	-0.047	-1.941	-0.020
Bus. rev % l.q.	$Q(\tilde{R}_B)$	Z_BREV_	-0.151	-5.193	-0.048
Size of SMSA group 2	$S2$	SIZE2	0.103	3.036	0.035
Size of SMSA group 3	$S3$	SIZE3	0.117	3.835	0.054
Size of SMSA group 4	$S4$	SIZE4	0.064	2.240	0.041
Size of SMSA group 5	$S5$	SIZE5	0.021	0.754	0.016

TABLE A.4: Regression results for specification # 4

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	9265	24	0.4858	0.4845	379.626

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	6.798	193.408	0.000
Agglomeration	A^*	LC6N	-0.099	-16.254	-0.165
Distance to POP	D^*	LATT	0.056	13.355	0.132
Electronic switch	K_1	SWTYPE1	-0.284	-20.551	-0.219
Remote switch	K_2	SWTYPE2	-0.469	-28.372	-0.263
Step-by-step switch	K_3	SWTYPE3	0.125	4.972	0.042
Crossbar switch	K_4	SWTYPE4	0.356	17.481	0.157
Revenue	R^*	LREV	-0.126	-30.935	-0.308
Employment growth	$\dot{E}^*$	LGEMP	-0.041	-3.921	-0.030
BELL SOUTH	h_1	HC1	-0.272	-16.430	-0.151
GTE	h_2	HC2	0.022	1.283	0.012
BELL ATLANTIC	h_3	HC3	-0.364	-19.381	-0.178
NYNEX	h_4	HC4	-0.123	-6.524	-0.060
AMERITECH	h_5	HC5	-0.063	-3.257	-0.030
USWEST	h_6	HC6	-0.308	-15.557	-0.144
SOUTHWESTERN BELL	h_7	HC7	-0.262	-11.069	-0.101
Nodal SMSAs	G_1	GROUP1	-0.124	-8.255	-0.079
Specialized Serv. SMSAs	G_2	GROUP2	-0.061	-3.447	-0.030
Production SMSAs	G_3	GROUP3	-0.072	-3.809	-0.031
Resort-Retirement SMSAs	G_4	GROUP4	-0.160	-5.788	-0.047
Size of SMSA group 2	$S2$	SIZE2	0.104	3.030	0.035
Size of SMSA group 3	$S3$	SIZE3	0.123	3.958	0.056
Size of SMSA group 4	$S4$	SIZE4	0.115	3.988	0.075
Size of SMSA group 5	$S5$	SIZE5	0.097	3.491	0.074

TABLE A.5: Regression results for specification # 5

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	9265	66 (incl. state dummies)	0.5223	0.5189	154.7610

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	7.079	133.985	0.000
Agglomeration	A^*	LC6N	-0.096	-15.421	-0.160
Distance to POP	D^*	LATT	0.068	16.130	0.160
Electronic switch	K_1	SWTYPE1	-0.313	-22.371	-0.242
Remote switch	K_2	SWTYPE2	-0.502	-30.115	-0.281
Step-by-step switch	K_3	SWTYPE3	0.104	4.076	0.035
Crossbar switch	K_4	SWTYPE4	0.333	16.486	0.147
Revenue	R^*	LREV	-0.131	-32.033	-0.320
Suburban	C_1	CNTY1	-0.036	-2.849	-0.028
Urban	C_2	CNTY2	-0.046	-2.907	-0.032
BELL SOUTH	h_1	HC1	-0.557	-19.850	-0.311
GTE	h_2	HC2	-0.096	-4.153	-0.053
BELL ATLANTIC	h_3	HC3	-0.547	-15.778	-0.268
NYNEX	h_4	HC4	0.108	1.129	0.053
AMERITECH	h_5	HC5	-0.176	-6.427	-0.083
USWEST	h_6	HC6	-0.503	-12.763	-0.235
SOUTHWESTERN BELL	h_7	HC7	-0.253	-6.497	-0.098
PACIFIC TELESIS	h_8	HC8	-0.301	-6.640	-0.114
CENTEL	h_9	HC9	-0.032	-0.873	-0.007
CONTEL	h_{10}	HC10	-0.216	-6.120	-0.059

TABLE A.6: Regression results for specification # 6

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	9265	18	0.4815	0.4805	505.148

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	6.898	272.202	0.000
Agglomeration	A^*	LC6N	-0.108	-17.476	-0.179
Distance to POP	D^*	LATT	0.056	13.236	0.132
Electronic switch	K_1	SWTYPE1	-0.291	-21.067	-0.225
Remote switch	K_2	SWTYPE2	-0.478	-28.786	-0.268
Step-by-step switch	K_3	SWTYPE3	0.128	5.112	0.044
Crossbar switch	K_4	SWTYPE4	0.350	17.186	0.155
Revenue	R^*	LREV	-0.131	-32.500	-0.320
Suburban	C_1	CNTY1	-0.060	-4.803	-0.046
Urban	C_2	CNTY2	-0.079	-5.031	-0.056
Employment growth	$\hat{E}^*$	LGEMP	-0.045	-4.325	-0.033
BELL SOUTH	h_1	HC1	-0.275	-16.619	-0.153
GTE	h_2	HC2	0.023	1.376	0.013
BELL ATLANTIC	h_3	HC3	-0.378	-20.254	-0.185
NYNEX	h_4	HC4	-0.127	-6.779	-0.062
AMERITECH	h_5	HC5	-0.057	-2.997	-0.027
USWEST	h_6	HC6	-0.290	-15.184	-0.136
SOUTHWESTERN BELL	h_7	HC7	-0.246	-10.405	-0.095

TABLE A.7: Regression results for specification # 7

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	9265	65 (incl. state dummies)	0.5497	0.5465	175.4840

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	3.788	26.108	0.000
Agglomeration	A^*	LC6N	-0.072	-12.240	-0.120
Distance to POP	D^*	LATT	0.055	13.613	0.128
Electronic switch	K_1	SWTYPE1	-0.279	-20.432	-0.216
Remote switch	K_2	SWTYPE2	-0.456	-27.980	-0.256
Step-by-step switch	K_3	SWTYPE3	0.095	3.836	0.032
Crossbar switch	K_4	SWTYPE4	0.346	17.649	0.153
Revenue	R^*	LREV	-0.119	-29.834	-0.291
Mean days until Eq. Ac.	Z^*	LSMSAEA	0.440	23.877	0.251
BELL SOUTH	h_1	HC1	-0.340	-11.814	-0.189
GTE	h_2	HC2	-0.030	-1.335	-0.017
BELL ATLANTIC	h_3	HC3	-0.293	-8.313	-0.144
NYNEX	h_4	HC4	0.115	1.246	0.056
AMERITECH	h_5	HC5	-0.046	-1.684	-0.021
USWEST	h_6	HC6	-0.293	-7.451	-0.137
SOUTHWESTERN BELL	h_7	HC7	-0.084	-2.190	-0.033
PACIFIC TELESIS	h_8	HC8	-0.246	-5.593	-0.093
CENTEL	h_9	HC9	0.003	0.093	0.001
CONTEL	h_{10}	HC10	-0.218	-6.386	-0.059

TABLE A.8: Regression results for specification # 8

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	7972	18	0.4668	0.4656	409.622

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	8.560	72.056	0.000
Agglomeration	A	C6N	-0.002	-5.179	-0.050
Distance to POP	D	ATT	0.003	12.247	0.121
Electronic switch	K_1	SWTYPE1	-413.000	-26.235	-0.314
Remote switch	K_2	SWTYPE2	-0.492	-26.056	-0.273
Step-by-step switch	K_3	SWTYPE3	0.089	3.331	0.032
Crossbar switch	K_4	SWTYPE4	0.225	10.625	0.105
Revenue	R	REV	-0.963	-32.125	-0.325
BELL SOUTH	h_1	HC1	-0.137	-5.083	-0.080
GTE	h_2	HC2	0.169	6.551	0.100
BELL ATLANTIC	h_3	HC3	-0.144	-5.195	-0.074
NYNEX	h_4	HC4	0.075	2.556	0.038
AMERITECH	h_5	HC5	0.089	3.223	0.044
USWEST	h_6	HC6	-0.137	-4.638	-0.067
SOUTHWESTERN BELL	h_7	HC7	-0.153	-5.027	-0.063
Information emp. l.q.	$Q(I)$	NI_E	-1.104	-9.094	-0.103
Non-intrastate % l.q.	$Q(M_2)$	N_BUSOUT	-0.035	-1.226	-0.014
Bus. rev % l.q.	$Q(R_B)$	N_BREV_	-0.179	-4.794	-0.048

TABLE A.9: Regression results for specification # 9

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	7972	18	0.4654	0.4643	407.405
Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	8.481	72.762	0.000
Agglomeration	A	C6N	-0.003	-5.952	-0.057
Distance to POP	D	ATT	0.003	12.370	0.122
Electronic switch	K_1	SWTYPE1	-0.415	-26.341	-0.316
Remote switch	K_2	SWTYPE2	-0.491	-25.942	-0.273
Step-by-step switch	K_3	SWTYPE3	0.093	3.445	0.033
Crossbar switch	K_4	SWTYPE4	0.221	10.426	0.103
Revenue	R	REV	-0.979	-32.807	-0.331
BELL SOUTH	h_1	HC1	-0.138	-5.191	-0.081
GTE	h_2	HC2	0.170	6.568	0.098
BELL ATLANTIC	h_3	HC3	-0.148	-5.371	-0.076
NYNEX	h_4	HC4	0.076	2.618	0.039
AMERITECH	h_5	HC5	0.088	3.188	0.044
USWEST	h_6	HC6	-0.131	-4.412	-0.064
SOUTHWESTERN BELL	h_7	HC7	-0.155	-5.081	-0.063
Information emp. l.q.	$Q(\tilde{I})$	ZI_E	-1.077	-8.984	-0.101
Non-intrastate % l.q.	$Q(\tilde{M}_2)$	Z_BUSOUT	-0.026	-0.954	-0.011
Bus. rev % l.q.	$Q(\tilde{R}_B)$	Z_BREV_	-0.126	-3.565	-0.036

TABLE A.10: Regression results for specification # 10

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	7972	20	0.4904	0.4892	402.874
Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	6.542	167.479	0.000
Agglomeration	A^*	LC6N	-0.091	-14.702	-0.157
Distance to POP	D^*	LATT	0.069	15.600	0.163
Electronic switch	K_1	SWTYPE1	-0.351	-22.252	-0.267
Remote switch	K_2	SWTYPE2	-0.550	-29.635	-0.305
Step-by-step switch	K_3	SWTYPE3	0.106	4.044	0.037
Crossbar switch	K_4	SWTYPE4	0.333	15.625	0.155
Revenue	R^*	LREV	-0.140	-31.238	-0.334
Employment growth	$\dot{E}^*$	LGEMP	-0.044	-4.182	-0.034
BELL SOUTH	h_1	HC1	-0.071	-3.084	-0.042
GTE	h_2	HC2	0.236	9.944	0.136
BELL ATLANTIC	h_3	HC3	-0.152	-6.125	-0.078
NYNEX	h_4	HC4	0.065	2.635	0.033
AMERITECH	h_5	HC5	0.170	6.683	0.084
USWEST	h_6	HC6	-0.107	-4.194	-0.053
SOUTHWESTERN BELL	h_7	HC7	-0.063	-2.213	-0.026
Size of SMSA group 2	$S2$	SIZE2	0.093	2.540	0.031
Size of SMSA group 3	$S3$	SIZE3	0.103	3.146	0.046
Size of SMSA group 4	$S4$	SIZE4	0.092	3.056	0.059
Size of SMSA group 5	$S5$	SIZE5	0.067	2.299	0.050

TABLE A.11: Regression results for specification # 11

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	7972	19	0.4950	0.4938	433.075

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	7.391	62.509	0.000
Agglomeration	A^*	LC6N	-0.080	-12.672	-0.138
Distance to POP	D^*	LATT	0.062	13.849	0.148
Electronic switch	K_1	SWTYPE1	-0.349	-22.232	-0.266
Remote switch	K_2	SWTYPE2	-0.557	-30.120	-0.309
Step-by-step switch	K_3	SWTYPE3	0.082	3.159	0.029
Crossbar switch	K_4	SWTYPE4	0.329	15.551	0.153
Revenue	R^*	LREV	-0.134	-29.493	-0.319
Employment growth	$\dot{E}^*$	LGEMP	-0.037	-3.496	-0.029
BELL SOUTH	h_1	HC1	-0.084	-3.207	-0.049
GTE	h_2	HC2	0.218	8.717	0.126
BELL ATLANTIC	h_3	HC3	-0.117	-4.345	-0.060
NYNEX	h_4	HC4	0.097	3.461	0.050
AMERITECH	h_5	HC5	0.166	6.225	0.082
USWEST	h_6	HC6	0.077	-2.681	-0.039
SOUTHWESTERN BELL	h_7	HC7	-0.054	-1.811	-0.022
Information emp. l.q.	$Q(I)$	NI_E	-0.552	-4.706	-0.051
Non-intrastate % l.q.	$Q(M_2)$	N_BUSOUT	-0.050	-1.779	-0.019
Bus. rev % l.q.	$Q(R_B)$	N_BREV_	-0.177	-4.875	-0.048

TABLE A.12: Regression results for specification # 12

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	7972	19	0.4937	0.4925	430.881

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	7.336	63.297	0.000
Agglomeration	A^*	LC6N	-0.085	-13.557	-0.146
Distance to POP	D^*	LATT	0.061	13.569	0.145
Electronic switch	K_1	SWTYPE1	-0.351	-22.300	-0.267
Remote switch	K_2	SWTYPE2	-0.557	-30.024	-0.309
Step-by-step switch	K_3	SWTYPE3	0.086	3.275	0.031
Crossbar switch	K_4	SWTYPE4	0.327	15.417	0.152
Revenue	R^*	LREV	-0.136	-29.936	-0.323
Employment growth	$\dot{E}^*$	LGEMP	-0.038	-3.613	-0.030
BELL SOUTH	h_1	HC1	-0.087	-3.380	-0.051
GTE	h_2	HC2	0.217	8.698	0.125
BELL ATLANTIC	h_3	HC3	-0.124	-4.610	-0.064
NYNEX	h_4	HC4	0.096	3.415	0.049
AMERITECH	h_5	HC5	0.163	6.128	0.081
USWEST	h_6	HC6	-0.740	-2.546	-0.036
SOUTHWESTERN BELL	h_7	HC7	-0.055	-1.863	-0.022
Information emp. l.q.	$Q(\tilde{I})$	ZI_E	-0.557	-4.822	-0.052
Non-intrastate % l.q.	$Q(\tilde{M}_2)$	Z_BUSOUT	-0.036	-1.391	-0.015
Bus. rev % l.q.	$Q(\tilde{R}_B)$	Z_BREV_	-0.121	-3.513	-0.034

TABLE A.13: Regression results for specification # 13

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	7972	23	0.4958	0.4944	355.275

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	7.324	60.024	0.000
Agglomeration	A^*	LC6N	-0.079	-12.337	-0.136
Distance to POP	D^*	LATT	0.062	13.823	0.148
Electronic switch	K_1	SWTYPE1	-0.348	-22.119	-0.265
Remote switch	K_2	SWTYPE2	-0.554	-29.891	-0.307
Step-by-step switch	K_3	SWTYPE3	0.085	3.246	0.030
Crossbar switch	K_4	SWTYPE4	0.331	15.621	0.154
Revenue	R^*	LREV	-0.134	-29.414	-0.319
Employment growth	$\dot{E}^*$	LGEMP	-0.036	-3.383	-0.028
BELL SOUTH	h_1	HC1	-0.086	-3.262	-0.050
GTE	h_2	HC2	0.214	8.527	0.124
BELL ATLANTIC	h_3	HC3	-0.122	-4.511	-0.063
NYNEX	h_4	HC4	0.089	3.135	0.045
AMERITECH	h_5	HC5	0.163	6.114	0.080
USWEST	h_6	HC6	-0.090	-3.071	-0.044
SOUTHWESTERN BELL	h_7	HC7	-0.059	-1.984	-0.024
Information emp. l.q.	$Q(I)$	NI_E	-0.567	-4.798	-0.053
Non-intrastate % l.q.	$Q(M_2)$	N_BUSOUT	-0.039	-1.396	-0.015
Bus. rev % l.q.	$Q(R_B)$	N_BREV_	-0.178	-4.867	-0.048
Size of SMSA group 2	$S2$	SIZE2	0.089	2.433	0.030
Size of SMSA group 3	$S3$	SIZE3	0.102	3.121	0.046
Size of SMSA group 4	$S4$	SIZE4	0.090	3.012	0.058
Size of SMSA group 5	$S5$	SIZE5	0.070	2.398	0.052

TABLE A.14: Regression results for specification # 14

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	7972	23	0.4956	0.4942	355.094

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	7.344	59.350	0.000
Agglomeration	A^*	LC6N	-0.079	-12.373	-0.136
Distance to POP	D^*	LATT	0.063	13.881	0.149
Electronic switch	K_1	SWTYPE1	-0.349	-22.152	-0.266
Remote switch	K_2	SWTYPE2	-0.554	-29.907	-0.308
Step-by-step switch	K_3	SWTYPE3	0.084	3.223	0.030
Crossbar switch	K_4	SWTYPE4	0.331	15.597	0.154
Revenue	R^*	LREV	-0.134	-29.470	-0.319
Employment growth	$\dot{E}^*$	LGEMP	-0.036	-3.374	-0.028
BELL SOUTH	h_1	HC1	-0.077	-2.979	-0.045
GTE	h_2	HC2	0.220	8.773	0.127
BELL ATLANTIC	h_3	HC3	-0.116	-4.290	-0.060
NYNEX	h_4	HC4	0.099	3.522	0.051
AMERITECH	h_5	HC5	0.169	6.334	0.084
USWEST	h_6	HC6	-0.081	-2.770	-0.040
SOUTHWESTERN BELL	h_7	HC7	-0.054	-1.820	-0.022
Information emp. l.q.	$Q(\tilde{I})$	ZI_E	-0.571	-4.903	-0.054
Non-intrastate % l.q.	$Q(\tilde{M}_2)$	Z_BUSOUT	-0.054	-2.052	-0.023
Bus. rev % l.q.	$Q(\tilde{R}_B)$	Z_BREV_	-0.156	-4.475	-0.044
Size of SMSA group 2	$S2$	SIZE2	0.094	2.586	0.031
Size of SMSA group 3	$S3$	SIZE3	0.104	3.180	0.047
Size of SMSA group 4	$S4$	SIZE4	0.079	2.606	0.050
Size of SMSA group 5	$S5$	SIZE5	0.026	0.903	0.020

TABLE A.15: Regression results for specification # 15

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	7972	20	0.4937	0.4925	408.196

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	6.677	222.310	0.000
Agglomeration	A^*	LC6N	-0.080	-12.558	-0.138
Distance to POP	D^*	LATT	0.065	14.497	0.154
Electronic switch	K_1	SWTYPE1	-0.343	-21.772	-0.261
Remote switch	K_2	SWTYPE2	-0.548	-29.624	-0.304
Step-by-step switch	K_3	SWTYPE3	0.098	3.783	0.035
Crossbar switch	K_4	SWTYPE4	0.337	15.912	0.157
Revenue	R^*	LREV	-0.133	-29.135	-0.318
Employment growth	$\dot{E}^*$	LGEMP	-0.040	-3.780	-0.031
BELL SOUTH	h_1	HC1	-0.080	-3.454	-0.047
GTE	h_2	HC2	0.235	9.911	0.135
BELL ATLANTIC	h_3	HC3	-0.139	-5.595	-0.072
NYNEX	h_4	HC4	0.076	3.096	0.039
AMERITECH	h_5	HC5	0.168	6.571	0.083
USWEST	h_6	HC6	-0.103	-4.048	-0.051
SOUTHWESTERN BELL	h_7	HC7	-0.066	-2.337	-0.027
Nodal SMSAs	G_1	GROUP1	-0.120	-7.746	-0.078
Specialized Serv. SMSAs	G_2	GROUP2	-0.070	-3.671	-0.034
Production SMSAs	G_3	GROUP3	-0.034	-1.706	-0.015
Resort-Retirement SMSAs	G_4	GROUP4	-0.111	-3.718	-0.032

TABLE A.16: Regression results for specification # 16

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	7972	24	0.4947	0.4933	338.385

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	6.588	165.143	0.000
Agglomeration	A^*	LC6N	-0.081	-12.637	-0.139
Distance to POP	D^*	LATT	0.063	14.038	0.150
Electronic switch	K_1	SWTYPE1	-0.342	-21.659	-0.260
Remote switch	K_2	SWTYPE2	-0.545	-29.468	-0.303
Step-by-step switch	K_3	SWTYPE3	0.101	3.868	0.036
Crossbar switch	K_4	SWTYPE4	0.339	15.977	0.158
Revenue	R^*	LREV	0.133	-29.055	-0.317
Employment growth	$\dot{E}^*$	LGEMP	-0.037	-3.462	-0.029
BELL SOUTH	h_1	HC1	-0.081	-3.472	-0.047
GTE	h_2	HC2	0.231	9.696	0.133
BELL ATLANTIC	h_3	HC3	-0.141	-5.650	-0.073
NYNEX	h_4	HC4	0.070	2.850	0.036
AMERITECH	h_5	HC5	0.167	6.512	0.083
USWEST	h_6	HC6	-0.110	-4.241	-0.054
SOUTHWESTERN BELL	h_7	HC7	-0.070	-2.434	-0.029
Nodal SMSAs	G_1	GROUP1	-0.126	-7.807	-0.082
Specialized Serv. SMSAs	G_2	GROUP2	-0.083	-4.232	-0.040
Production SMSAs	G_3	GROUP3	-0.044	-2.158	-0.019
Resort-Retirement SMSAs	G_4	GROUP4	-0.122	-4.061	-0.035
Size of SMSA group 2	$S2$	SIZE2	0.075	2.044	0.025
Size of SMSA group 3	$S3$	SIZE3	0.102	3.115	0.046
Size of SMSA group 4	$S4$	SIZE4	0.117	3.848	0.075
Size of SMSA group 5	$S5$	SIZE5	0.099	3.377	0.074

TABLE A.17: Regression results for specification # 17

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	7972	17	0.5247	0.5238	549.029

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	3.560	27.615	0.000
Agglomeration	A^*	LC6N	-0.064	-10.697	-0.111
Distance to POP	D^*	LATT	0.053	12.427	0.126
Electronic switch	K_1	SWTYPE1	-0.306	-19.955	-0.232
Remote switch	K_2	SWTYPE2	-0.501	-27.833	-0.278
Step-by-step switch	K_3	SWTYPE3	0.084	3.367	0.030
Crossbar switch	K_4	SWTYPE4	0.339	16.522	0.158
Revenue	R^*	LREV	-0.123	-27.967	-0.293
Mean days until Eq. Ac.	Z^*	LSMSAEA	0.438	24.274	0.238
Employment growth	$\dot{E}^*$	LGEMP	-0.009	-0.093	-0.007
BELL SOUTH	h_1	HC1	-0.054	-2.405	-0.031
GTE	h_2	HC2	0.187	8.150	0.108
BELL ATLANTIC	h_3	HC3	-0.044	-1.836	-0.023
NYNEX	h_4	HC4	0.028	1.170	0.014
AMERITECH	h_5	HC5	0.174	7.063	0.086
USWEST	h_6	HC6	-0.069	-2.831	-0.034
SOUTHWESTERN BELL	h_7	HC7	0.002	0.057	0.001

TABLE A.18: Regression results for specification # 18

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	1472	64 (incl. state dummies)	0.5197	0.4982	24.1980

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	7.019	71.814	0.000
Agglomeration	A^*	LC6N	-0.096	-5.298	-0.133
Distance to POP	D^*	LATT	0.061	6.079	0.149
Electronic switch	K_1	SWTYPE1	-0.175	-6.277	-0.163
Remote switch	K_2	SWTYPE2	-0.412	-13.784	-0.325
Step-by-step switch	K_3	SWTYPE3	0.176	4.295	0.095
Crossbar switch	K_4	SWTYPE4	0.387	10.513	0.248
Revenue	R^*	LREV	-0.148	-14.290	-0.365
BELL SOUTH	h_1	HC1	-0.575	-11.709	-0.390
GTE	h_2	HC2	-0.112	-2.816	-0.085
BELL ATLANTIC	h_3	HC3	-0.550	-8.885	-0.305
NYNEX	h_4	HC4	-0.006	-0.049	-0.003
AMERITECH	h_5	HC5	-0.206	-3.959	-0.113
USWEST	h_6	HC6	-0.443	-6.259	-0.282
SOUTHWESTERN BELL	h_7	HC7	-0.361	-5.095	-0.186
PACIFIC TELESIS	h_8	HC8	-0.372	-4.278	-0.165
CENTEL	h_9	HC9	-0.101	-1.489	-0.032
CONTEL	h_{10}	HC10	-0.173	-2.383	-0.052

TABLE A.19: Regression results for specification # 19

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	1472	66 (incl. state dummies)	0.5210	0.4989	23.5450

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	6.933	64.883	0.000
Agglomeration	A^*	LC6N	-0.097	-5.363	-0.134
Distance to POP	D^*	LATT	0.066	6.257	0.163
Electronic switch	K_1	SWTYPE1	-0.173	-6.225	-0.162
Remote switch	K_2	SWTYPE2	-0.412	-13.802	-0.325
Step-by-step switch	K_3	SWTYPE3	0.181	4.420	0.097
Crossbar switch	K_4	SWTYPE4	0.392	10.626	0.251
Revenue	R^*	LREV	-0.149	-14.371	-0.369
Suburban	C_1	CNTY1	0.088	1.743	0.061
Urban	C_2	CNTY2	0.087	1.962	0.072
BELL SOUTH	h_1	HC1	-0.583	-11.829	-0.395
GTE	h_2	HC2	-0.115	-2.891	-0.087
BELL ATLANTIC	h_3	HC3	-0.567	-9.076	-0.314
NYNEX	h_4	HC4	-0.011	-0.082	-0.005
AMERITECH	h_5	HC5	-0.206	-3.952	-0.113
USWEST	h_6	HC6	-0.450	-6.349	-0.287
SOUTHWESTERN BELL	h_7	HC7	-0.365	-5.147	-0.188
PACIFIC TELESIS	h_8	HC8	-0.372	-4.282	-0.165
CENTEL	h_9	HC9	-0.097	-1.438	-0.030
CONTEL	h_{10}	HC10	-0.173	-2.393	-0.052

TABLE A.20: Regression results for specification # 20

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
WLS	1472	64 (incl. state dummies)	0.6170	0.5999	36.031

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	6.974	76.313	0.000
Agglomeration	A^*	LC6N	-0.100	-6.223	-0.150
Distance to POP	D^*	LATT	0.068	6.868	0.159
Electronic switch	K_1	SWTYPE1	-0.216	-8.499	-0.208
Remote switch	K_2	SWTYPE2	0-.467	-16.684	-0.354
Step-by-step switch	K_3	SWTYPE3	0.148	3.698	0.072
Crossbar switch	K_4	SWTYPE4	0.376	10.878	0.229
Revenue	R^*	LREV	-0.159	-15.283	-0.390
BELL SOUTH	h_1	HC1	-0.566	-12.301	-0.390
GTE	h_2	HC2	-0.095	-2.515	-0.069
BELL ATLANTIC	h_3	HC3	-0.555	-9.760	-0.327
NYNEX	h_4	HC4	0.068	0.498	0.038
AMERITECH	h_5	HC5	-0.174	-3.666	-0.099
USWEST	h_6	HC6	-0.463	-7.129	-0.288
SOUTHWESTERN BELL	h_7	HC7	-0.275	-4.172	-0.139
PACIFIC TELESIS	h_8	HC8	-0.339	-4.322	-0.157
CENTEL	h_9	HC9	-0.066	-1.087	-0.021
CONTEL	h_{10}	HC10	-0.186	-2.933	-0.059

TABLE A.21: Regression results for specification # 21

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
WLS	1472	66 (incl. state dummies)	0.6174	0.5997	34.9260

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	6.938	68.613	0.000
Agglomeration	A^*	LC6N	-0.101	-6.271	-0.151
Distance to POP	D^*	LATT	0.072	6.811	0.170
Electronic switch	K_1	SWTYPE1	-0.215	-8.443	-0.207
Remote switch	K_2	SWTYPE2	-0.467	-16.680	-0.354
Step-by-step switch	K_3	SWTYPE3	0.149	3.717	0.073
Crossbar switch	K_4	SWTYPE4	0.378	10.923	0.230
Revenue	R^*	LREV	-0.159	-15.214	-0.391
Suburban	C_1	CNTY1	0.022	0.478	0.015
Urban	C_2	CNTY2	0.041	1.015	0.033
BELL SOUTH	h_1	HC1	-0.568	-12.332	-0.391
GTE	h_2	HC2	-0.095	-2.516	-0.070
BELL ATLANTIC	h_3	HC3	-0.560	-9.769	-0.329
NYNEX	h_4	HC4	0.067	0.488	0.037
AMERITECH	h_5	HC5	-0.173	-3.641	-0.099
USWEST	h_6	HC6	-0.465	-7.152	-0.289
SOUTHWESTERN BELL	h_7	HC7	-0.276	-4.191	-0.140
PACIFIC TELESIS	h_8	HC8	-0.337	-4.294	-0.156
CENTEL	h_9	HC9	0.0650	-1.066	-0.021
CONTEL	h_{10}	HC10	-0.184	-2.894	-0.058

TABLE A.22: Regression results for specification # 22

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	1218	23	0.4629	0.4530	46.8460

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	7.050	29.763	0.000
Agglomeration	A^*	LC6N	-0.080	-4.015	-0.114
Distance to POP	D^*	LATT	0.045	4.218	0.116
Electronic switch	K_1	SWTYPE1	-0.243	-7.070	-0.224
Remote switch	K_2	SWTYPE2	-0.427	-12.453	-0.341
Step-by-step switch	K_3	SWTYPE3	0.202	4.468	0.114
Crossbar switch	K_4	SWTYPE4	0.376	9.195	0.260
Revenue	R^*	LREV	-0.141	-11.962	-0.344
Employment growth	$\dot{E}^*$	LGEMP	-0.026	-1.271	-0.028
BELL SOUTH	h_1	HC1	0.004	0.076	0.003
GTE	h_2	HC2	0.368	7.067	0.300
BELL ATLANTIC	h_3	HC3	0.041	0.697	0.025
NYNEX	h_4	HC4	0.169	2.747	0.094
AMERITECH	h_5	HC5	0.267	4.631	0.160
USWEST	h_6	HC6	0.100	1.708	0.069
SOUTHWESTERN BELL	h_7	HC7	0.018	0.307	0.010
Information emp. l.q.	$Q(I)$	NI_E	-0.437	-1.923	-0.047
Non-intrastate % l.q.	$Q(M_2)$	N_BUSOUT	-0.117	-2.169	-0.059
Bus. rev % l.q.	$Q(R_B)$	N_BREV_	-0.058	-0.899	-0.022
Size of SMSA group 2	$S2$	SIZE2	-0.022	-0.511	-0.015
Size of SMSA group 3	$S3$	SIZE3	0.006	0.149	0.005
Size of SMSA group 4	$S4$	SIZE4	-0.012	-0.306	-0.010
Size of SMSA group 5	$S5$	SIZE5	-0.022	-0.577	-0.020

TABLE A.23: Regression results for specification # 23

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	1218	23	0.4634	0.4535	46.9440

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	7.059	29.464	0.000
Agglomeration	A^*	LC6N	-0.078	-4.029	-0.115
Distance to POP	D^*	LATT	0.046	4.259	0.117
Electronic switch	K_1	SWTYPE1	-0.242	-7.057	-0.223
Remote switch	K_2	SWTYPE2	-0.427	-12.467	-0.341
Step-by-step switch	K_3	SWTYPE3	0.201	4.457	0.114
Crossbar switch	K_4	SWTYPE4	0.376	9.207	0.260
Revenue	R^*	LREV	-0.141	-11.990	-0.345
Employment growth	$\dot{E}^*$	LGEMP	-0.026	-1.247	-0.028
BELL SOUTH	h_1	HC1	0.009	0.162	0.006
GTE	h_2	HC2	0.371	7.135	0.302
BELL ATLANTIC	h_3	HC3	0.046	0.775	0.028
NYNEX	h_4	HC4	0.175	2.855	0.098
AMERITECH	h_5	HC5	0.271	4.696	0.162
USWEST	h_6	HC6	0.107	1.828	0.074
SOUTHWESTERN BELL	h_7	HC7	0.022	0.368	0.012
Information emp. l.q.	$Q(\tilde{I})$	ZI_E	-0.439	-1.968	-0.048
Non-intrastate % l.q.	$Q(\tilde{M}_2)$	Z_BUSOUT	-0.118	-2.426	-0.065
Bus. rev % l.q.	$Q(\tilde{R}_B)$	Z_BREV_	-0.051	-0.873	-0.021
Size of SMSA group 2	$S2$	SIZE2	-0.013	-0.292	-0.008
Size of SMSA group 3	$S3$	SIZE3	0.016	0.386	0.012
Size of SMSA group 4	$S4$	SIZE4	-0.016	-0.421	-0.014
Size of SMSA group 5	$S5$	SIZE5	-0.051	-1.340	-0.047

TABLE A.24: Regression results for specification # 24

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	1218	24	0.4605	0.4501	44.3540

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	6.483	88.368	0.000
Agglomeration	A^*	LC6N	-0.085	-4.348	-0.124
Distance to POP	D^*	LATT	0.047	4.456	0.120
Electronic switch	K_1	SWTYPE1	-0.239	-6.973	-0.221
Remote switch	K_2	SWTYPE2	-0.423	-12.292	-0.338
Step-by-step switch	K_3	SWTYPE3	0.209	4.619	0.118
Crossbar switch	K_4	SWTYPE4	0.382	9.373	0.264
Revenue	R^*	LREV	-0.141	-11.918	-0.346
Employment growth	$\dot{E}^*$	LGEMP	-0.033	-1.613	-0.036
BELL SOUTH	h_1	HC1	-0.017	-0.327	-0.012
GTE	h_2	HC2	0.354	7.037	0.288
BELL ATLANTIC	h_3	HC3	-0.013	-0.235	-0.008
NYNEX	h_4	HC4	0.119	2.085	0.066
AMERITECH	h_5	HC5	0.244	4.336	0.146
USWEST	h_6	HC6	0.057	1.060	0.039
SOUTHWESTERN BELL	h_7	HC7	-0.001	-0.016	-0.001
Nodal SMSAs	G_1	GROUP1	-0.085	-2.309	-0.060
Specialized Serv. SMSAs	G_2	GROUP2	0.038	0.999	0.025
Production SMSAs	G_3	GROUP3	0.006	0.164	0.004
Resort-Retirement SMSAs	G_4	GROUP4	-0.035	-0.462	-0.010
Size of SMSA group 2	$S2$	SIZE2	0.019	-0.441	-0.013
Size of SMSA group 3	$S3$	SIZE3	0.011	0.268	0.008
Size of SMSA group 4	$S4$	SIZE4	-0.014	-0.338	-0.011
Size of SMSA group 5	$S5$	SIZE5	-0.003	-0.075	-0.003

TABLE A.25: Regression results for specification # 25

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
OLS	1218	18	0.4568	0.4491	59.4000

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	6.486	79.955	6.000
Agglomeration	A^*	LC6N	-0.091	-4.883	-0.133
Distance to POP	D^*	LATT	0.042	3.932	0.109
Electronic switch	K_1	SWTYPE1	-0.236	-6.884	-0.217
Remote switch	K_2	SWTYPE2	-0.427	-12.431	-0.341
Step-by-step switch	K_3	SWTYPE3	0.207	4.574	0.117
Crossbar switch	K_4	SWTYPE4	0.378	9.263	0.261
Revenue	R^*	LREV	-0.144	-12.209	-0.353
Suburban	C_1	CNTY1	0.028	0.650	0.024
Urban	C_2	CNTY2	-0.013	-0.303	-0.012
Employment growth	$\dot{E}^*$	LGEMP	-0.034	-1.669	-0.037
BELL SOUTH	h_1	HC1	-0.037	-0.730	-0.027
GTE	h_2	HC2	0.336	6.743	0.274
BELL ATLANTIC	h_3	HC3	-0.026	-0.474	-0.016
NYNEX	h_4	HC4	0.106	1.874	0.059
AMERITECH	h_5	HC5	0.237	4.243	0.142
USWEST	h_6	HC6	0.033	0.631	0.023
SOUTHWESTERN BELL	h_7	HC7	-0.018	-0.308	-0.010

TABLE A.26: Regression results for specification # 26

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
WLS	1218	23	0.5831	0.5754	76.029

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	7.223	32.501	0.000
Agglomeration	A^*	LC6N	-0.080	-4.618	-0.127
Distance to POP	D^*	LATT	0.044	4.100	0.106
Electronic switch	K_1	SWTYPE1	-0.283	-9.279	-0.274
Remote switch	K_2	SWTYPE2	-0.491	-15.374	-0.371
Step-by-step switch	K_3	SWTYPE3	0.161	3.716	0.082
Crossbar switch	K_4	SWTYPE4	0.364	9.639	0.238
Revenue	R^*	LREV	-0.151	-13.121	-0.370
Employment growth	$\dot{E}^*$	LGEMP	-0.030	-1.581	-0.031
BELL SOUTH	h_1	HC1	-0.047	-1.025	-0.035
GTE	h_2	HC2	0.294	6.635	0.230
BELL ATLANTIC	h_3	HC3	-0.041	-0.841	-0.027
NYNEX	h_4	HC4	0.132	2.579	0.079
AMERITECH	h_5	HC5	0.209	4.299	0.129
USWEST	h_6	HC6	0.011	0.226	0.008
SOUTHWESTERN BELL	h_7	HC7	-0.018	-0.338	-0.010
Information emp. l.q.	$Q(I)$	NI_E	-0.548	-2.592	-0.062
Non-intrastate % l.q.	$Q(M_2)$	N_BUSOUT	-0.092	-1.874	-0.046
Bus. rev % l.q.	$Q(R_B)$	N_BREV_	-0.110	-1.815	-0.040
Size of SMSA group 2	$S2$	SIZE2	0.017	0.359	0.010
Size of SMSA group 3	$S3$	SIZE3	0.033	0.760	0.023
Size of SMSA group 4	$S4$	SIZE4	0.017	0.417	0.014
Size of SMSA group 5	$S5$	SIZE5	0.010	0.268	0.010

TABLE A.27: Regression results for specification # 27

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
WLS	1218	23	0.5834	0.5757	76.116

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	7.236	32.144	0.000
Agglomeration	A^*	LC6N	-0.080	-4.638	-0.127
Distance to POP	D^*	LATT	0.044	4.155	0.108
Electronic switch	K_1	SWTYPE1	-0.282	-9.265	-0.273
Remote switch	K_2	SWTYPE2	-0.491	-15.390	-0.371
Step-by-step switch	K_3	SWTYPE3	0.160	3.702	0.082
Crossbar switch	K_4	SWTYPE4	0.364	9.650	0.238
Revenue	R^*	LREV	-0.151	-13.162	-0.370
Employment growth	$\dot{E}^*$	LGEMP	-0.030	-1.562	-0.030
BELL SOUTH	h_1	HC1	-0.042	-0.912	-0.031
GTE	h_2	HC2	0.298	6.735	0.233
BELL ATLANTIC	h_3	HC3	-0.037	-0.744	-0.023
NYNEX	h_4	HC4	0.139	2.734	0.084
AMERITECH	h_5	HC5	0.213	4.387	0.131
USWEST	h_6	HC6	0.019	0.373	0.013
SOUTHWESTERN BELL	h_7	HC7	-0.014	-0.264	-0.008
Information emp. l.q.	$Q(\tilde{I})$	ZI_E	-0.548	-2.640	-0.063
Non-intrastate % l.q.	$Q(\tilde{M}_2)$	Z_BUSOUT	-0.098	-2.199	-0.054
Bus. rev % l.q.	$Q(\tilde{R}_B)$	Z_BREV_	-0.096	-1.706	-0.037
Size of SMSA group 2	$S2$	SIZE2	0.025	0.525	0.014
Size of SMSA group 3	$S3$	SIZE3	0.040	0.916	0.027
Size of SMSA group 4	$S4$	SIZE4	0.008	0.206	0.007
Size of SMSA group 5	$S5$	SIZE5	-0.027	-0.678	-0.026

TABLE A.28: Regression results for specification # 28

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
WLS	1218	24	0.5800	0.5720	71.6920

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	6.522	92.294	0.000
Agglomeration	A^*	LC6N	-0.083	-4.784	-0.133
Distance to POP	D^*	LATT	0.047	4.450	0.113
Electronic switch	K_1	SWTYPE1	-0.278	-9.080	-0.269
Remote switch	K_2	SWTYPE2	-0.485	-15.131	-0.366
Step-by-step switch	K_3	SWTYPE3	0.172	3.958	0.088
Crossbar switch	K_4	SWTYPE4	0.371	9.791	0.242
Revenue	R^*	LREV	-0.152	-12.986	-0.371
Employment growth	$\dot{E}^*$	LGEMP	-0.035	-1.831	-0.036
BELL SOUTH	h_1	HC1	-0.060	-1.427	-0.045
GTE	h_2	HC2	0.292	6.840	0.228
BELL ATLANTIC	h_3	HC3	-0.084	-1.809	-0.054
NYNEX	h_4	HC4	0.089	1.908	0.054
AMERITECH	h_5	HC5	0.196	4.150	0.121
USWEST	h_6	HC6	-0.029	-0.639	-0.020
SOUTHWESTERN BELL	h_7	HC7	-0.037	-0.733	-0.020
Nodal SMSAs	G_1	GROUP1	-0.111	-3.532	-0.086
Specialized Serv. SMSAs	G_2	GROUP2	-0.028	-0.832	-0.019
Production SMSAs	G_3	GROUP3	-0.022	-0.676	-0.014
Resort-Retirement SMSAs	G_4	GROUP4	-0.076	-1.303	-0.027
Size of SMSA group 2	$S2$	SIZE2	0.013	0.269	0.007
Size of SMSA group 3	$S3$	SIZE3	0.038	0.859	0.026
Size of SMSA group 4	$S4$	SIZE4	0.035	0.839	0.030
Size of SMSA group 5	$S5$	SIZE5	0.039	0.970	0.038

TABLE A.29: Regression results for specification # 29

Summary Statistics					
Method	# of obs.	# of variables	R^2	Adjusted R^2	F
WLS	1218	18	0.5753	0.5693	95.689

Parameter Estimates					
description	*variable*	*SAS name*	*parameter*	*t-statistic*	*standardized estimates*
		INTERCEPT	6.557	82.603	0.000
Agglomeration	A^*	LC6N	-0.100	-6.152	-0.159
Distance to POP	D^*	LATT	0.045	4.156	0.108
Electronic switch	K_1	SWTYPE1	-0.274	-8.939	-0.265
Remote switch	K_2	SWTYPE2	-0.491	-15.289	-0.371
Step-by-step switch	K_3	SWTYPE3	0.174	3.990	0.089
Crossbar switch	K_4	SWTYPE4	0.372	9.808	0.243
Revenue	R^*	LREV	-0.157	-13.485	-0.384
Suburban	C_1	CNTY1	-0.014	-0.285	-0.009
Urban	C_2	CNTY2	-0.041	-0.943	-0.034
Employment growth	$\dot{E}^*$	LGEMP	-0.038	-1.993	-0.039
BELL SOUTH	h_1	HC1	-0.074	-1.736	-0.055
GTE	h_2	HC2	0.281	6.599	0.219
BELL ATLANTIC	h_3	HC3	-0.106	-2.284	-0.068
NYNEX	h_4	HC4	0.076	1.652	0.046
AMERITECH	h_5	HC5	0.186	3.953	0.115
USWEST	h_6	HC6	-0.041	-0.912	-0.027
SOUTHWESTERN BELL	h_7	HC7	-0.035	-0.701	-0.019

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