Telecommunications Infrastructure in the Southeastern United States

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Executive Summary

This research extends our earlier research, which examined variations in telecommunications levels-of-service in one southeastern state, Tennessee (Malecki and Boush 1999). The present work encompasses four southeastern states: Kentucky, Mississippi, North Carolina, and Tennessee. This research analyzes the capabilities of central office (CO) switches in the four states, providing details on local variation in telecommunications technologies. We have used a data set which includes the location, features, and functionality of each switch.

We use a proposed six-level hierarchy of digital capability in the switches, ranging from the absence of international direct long distance dialing (IDDD) through multi-rate integrated services digital network (ISDN) capability. Most switches conform to that hierarchy, with all lower levels of capability being present at any given level. We hypothesize that rural areas will be underserved by advanced telecommunications services, and that urban areas are more likely to have higher levels of service. The rural-urban distinction accounts for much, but not all, of the pattern found in the four states. The general pattern is that the number of switches in metro areas with basic capability drops off much less as we move up the hierarchy to advanced data capability than is the case in rural areas.

All but one of the 397 counties in the four states has at least one CO switch. The central counties of the region's large metropolitan areas (Louisville and Lexington in Kentucky, Jackson in Mississippi, Charlotte, Greensboro-Winston-Salem, and Raleigh-Durham in North Carolina, and Nashville, Memphis, Knoxville, and Chattanooga in Tennessee) together contain 416 switches, or 20.6% of the 2017 switches in the four states.

As one would expect, the number of switches is related to the number of residential and business customers. Statistically, the number of switches in a county is primarily a function of a county's population but, even more significantly in three states, of the number of business establishments in the county. Using the Economic Research Service Rural-Urban Continuum Code (Beale code) for each county, the mean number of CO switches per county is highest in the metro counties and lowest in the most rural counties.

Standing out sharply in the four states is the contrast between metropolitan (metro) and nonmetropolitan (nonmetro) counties where Level 1 or 2 is the highest level switch in a county, versus those with a Level 3 or higher switch. When aggregated in this way, the difference between metro counties and nonmetro counties and the highest level of CO switch is highly statistically significant.

The highest-capability switches are concentrated disproportionately in metropolitan areas, largely in response to larger numbers of business establishments. Rural counties, on the other hand, are more likely to have both fewer switches and switches with lower levels of digital capability, except in places with progressive service providers which are much better-served in digital capability. Similarly, the level of capability is primarily a response to county population and population density.

The overall picture in the Southeast is one of tremendous variation—variation across states and variation within the four states being studied. Rural (nonmetro) counties generally, but not always, have both fewer switches and switches with lower levels of digital capability. However, North Carolina and Tennessee, the two most urban of the four states, also have seen the greatest entry by new telecommunications competitors. These two states have the largest percentages of advanced (digital) switches in both metro and rural counties. In Kentucky and Mississippi, there are small areas with high levels of digital switch capability, but these are not widespread. On the whole, it is residents of metropolitan—not rural—areas who are most likely to be served by higher levels of digital telecommunications.

1. Introduction

This research examines variations in telecommunications infrastructure and levels-of-service in four southeastern states located largely within the TVA region: Kentucky, Mississippi, North Carolina, and Tennessee. Tennessee was the focus of an earlier project (Malecki and Boush 1999), updated and supplemented here with comparisons to the other three states. The purpose is to learn more about geographical variations in the provision of digital telecommunications technologies, which are increasingly important as data transmission via the Internet becomes more and more an ordinary part of American life and business.

The report is organized as follows: the next section outlines the context of technology in telecommunications and its geographical variations; Section 3 describes telephone central office switches, especially digital switches; Section 4 describes the data set analyzed in this report; Section 5 sets switch provision and its providers in the four states within the national context and presents a comparison of switch provision in the four states; Section 6 sets forth the proposed level-of-service hierarchy, and presents comparisons across the four states in several characteristics of telecommunications infrastructure; Section 7 presents results of attempts to account statistically for the both the variation in number of central office switches and variation in the highest level of telephone switch capability in counties in the four states; finally, Section 8 presents conclusions and implications of the findings for rural residents in the four states.

2. Telecommunications Technology

Technological change in telecommunications does not benefit everyone equally. Social and economic differences among people provide one type of variation, documented as the “digital divide” (NTIA 1999). Several geographical patterns also vary, among them lower rates of Internet use among rural U.S. residents. Why does this occur? First, both technological change, such as fiber-optic cabling and deregulation have permitted high-quality transmission over long distances, and have prompted a general decrease in the cost of service—but not for everyone. Coast-to-coast linkages are the top priority of virtually all telecommunications providers in the United States, and especially new providers, in order to benefit from the large business markets on the East Coast, in California, and in large cities in between. New technologies follow the characteristic hierarchical diffusion pattern: beginning first in large cities, where the largest markets are found, and then to progressively smaller places. The large-city business routes, connecting markets in New York, the Boston-Washington corridor, and then Chicago to Los Angeles and San Francisco (via Texas and Colorado), are the consistent priority of telecommunications providers, both in conventional telephone networks (Langdale 1983) and in Internet backbones (Moss and Townsend 1998; Wheeler and O’Kelly 1999). Greater choice and newer, higher-quality telecommunications technology are most available in the largest cities.

Second, rural areas generally are disadvantaged when it comes to telecommunications technologies (Conte 1999; Parker et al. 1995; Rowley 1999). Being unable to muster the demand needed to justify or amortize large infrastructure investments, rural areas are less likely to see the complete set of telecommunications innovations. New technologies that enable the latest broadband (high-speed) capability, needed for multimedia (audio, video) transmission, are implemented first in urban markets (Akimaru et al. 1997; Conte 1999; *Fortune* 1999; Lu et al. 1998). The reason is clear: urban areas represent greater spatial density of demand, where suppliers prefer to make investments, because the market is big enough to generate high returns per line (Salomon 1988).

Third, dramatic improvements in the computational power and networkability of computers have created new demands for data transmission, with the result that data transfer has surpassed voice in the quantity of traffic on the public network (Coffman and Odlyzko 1998). Many new technologies focus on data rather than voice transmission. Access to the World Wide Web and its graphical interface has meant that high-speed (broadband) capability, low error rates (packet loss), and ready connectivity are the hallmarks of high-quality communications from the point of view of today’s consumer. To minimize delays in transmission, greater-than-needed capacity is installed in order to keep utilization below overload conditions (Akimaru et al. 1997; Lu et al. 1998). Redundancy in the Internet backbone on some city-pairs, such as San Francisco–Los Angeles, New York–Washington, and Washington–Atlanta, is considerable: 20 or more providers operate direct fiber-optic service on each of these links (Moss and Townsend 1998). However, not every city is served by every firm, and rural areas are the least served by fiber. Overall, broadband access is disproportionately available in large urban areas.

Only a few years ago, quality-of-service in telecommunications meant the availability of a dial-tone and reliable service. The few variables monitored by the U.S. Federal Communications Commission (FCC) included number of seconds delay for a dial-tone, number of service complaints, and time without telephone service (outage line-minutes, switches with downtime) (Kraushaar, 1995). Universal service, formerly nothing more than availability of plain old telephone service (POTS), is now seen as access to the Internet (Kim 1998), but this is difficult to coordinate with deregulation and incentives for investment in innovation (Darby and Fuhr 1998). It has become clear that Internet access is not available equally, with the greatest "digital divide" being along the lines of race, income, and education (Hoffman and Novak 1998; NTIA 1999; Wolf 1998).

Recent analyses of Internet backbones have ranked U.S. cities or metropolitan areas according to measures of their Internet connectivity (Malecki and Gorman, 2000; Moss and Townsend 1998; Wheeler and O'Kelly 1999). Several different measures are used, with slightly different results, but San Francisco, Washington, and Dallas generally outrank the much larger areas of New York and Los Angeles, suggesting that Internet accessibility is responding to demand beyond that measured by population alone. This finding is especially strong when bandwidth-weighted links are analyzed (Malecki and Gorman 2000; Moss and Townsend 1998). High-speed bandwidth is concentrated in large urban areas even more than slower forms of Internet access, a fact that constrains companies as well as individual users (Conte 1999; Rupley 1999).

In the four TVA states studied in this report, seven metro areas among the 58 MSAs are served by Internet backbones: Raleigh-Durham–Chapel Hill, Charlotte–Gastonia–Rock Hill, and Greensboro–Winston-Salem–High Point in North Carolina, Nashville and Chattanooga in Tennessee, Louisville, Kentucky, and Jackson, Mississippi. Raleigh-Durham was served by the greatest total bandwidth of fiber-optic links: 540 Mbps, followed by Charlotte (360 Mbps), Chattanooga (225 Mbps), and the other four, all of which had 180 Mbps in total bandwidth available in late 1998 (Malecki and Gorman 2000). Both the available bandwidth and the capability of the local switch determine the speed of a customer's "download."

Bandwidth is a critical element in the transmission of data, which are increasingly in the form of graphics, videos, and sound clips. A relatively simple "Web page" can contain 1 megabyte (Mb) or more of data. Demand by more users for more Internet content of all kinds means that a larger number of "packets" are traversing the fiber-optic cables of the network. Moreover, "the congestion caused by video use is pernicious; it destroys some valuable mechanisms that are part of the Internet's discipline and efficiency" (Srinagesh 1997: 136). As a result, most backbone providers are upgrading from DS-3 (T-3; 45 Mbps) links to high-bandwidth OC-3 (155 Mbps) and faster (*Boardwatch* 1999).

Deregulation and Competition

Occurring simultaneously with technological convergence and the emergence of the Internet as a phenomenon, deregulation in telecommunications has catalyzed competition. Although the FCC has continued to have a strong influence on voice telephone service, it has treated data services as a separate category, virtually free of regulation (Kennard 1999; Leo and Huber 1997). Recent analyses conclude that deregulation has been incomplete and, in fact, that competition has been thwarted by lingering regulation (Kahn et al. 1999; Kaserman and Mayo 1999).

The incumbent local exchange carriers (ILECs)—a category that includes the Regional Bell Operating Companies (RBOCs) or Baby Bells (many subsequently merged), independent carriers such as GTE and Sprint, and hundreds of small firms and coops—have been joined (particularly since the Telecommunications Act of 1996) by hundreds of competitive local exchange carriers (CLECs). This group includes wireless carriers, competitive access providers (CAPs) of advanced fiber networks (many of which predated the 1996 Act), and personal communications services (PCS). Some states had permitted local competitors in advance of the federal Telecommunications Act of 1996. "Unbundling" allows CLECs to buy access to the "network elements" (local loops, network interface devices, switches, transmission facilities, signaling and call-related databases, operation support systems, and directory assistance facilities) of ILECs rather than build their own facilities. Unbundling may be slowing the development of network infrastructure by discouraging investment because it is so easy to resell services through an ILEC's network (Aron et al. 1998; Perrin 1998; Woroch 1998). The FCC (1998) found that, overall, CLECs have invested more heavily in fiber, concentrated in urban areas and, within urban areas, in co-location at switches with high capacity lines. LECs have been spending more on advertising than on new technology (Kim 1998).

In addition, in the convergence between the Internet and conventional telecommunications, there is an emerging trend for CLECs to acquire Internet service providers (ISPs) or, alternatively, for ISPs to become CLECs within their service area. Such "ISPCLECs can offer much more than local phone service" by providing Internet access, helped by hardware firms such as Northern Telecom (1998). A recent U.S. Supreme Court decision makes ISPCLECs the growth segment of the industry, in part because of the minimal investment required for facilities (Geist 1999).

3. Central Office (CO) Switches and Digital Switch Technology

The local telephone network relies both on the "loop" of copper wires and fiber-optic cables and on the technology of the central office (CO) switch. The CO switch, a specialized mainframe computer that routes phones calls toward their destination, has grown well beyond being a simple replacement for manual operators. Sophisticated software (signaling system 7–SS7) permits caller identification, call waiting, 800 and 900 services, custom billing and other information services (Heldman 1997). The quality of *local* service—and of an individual customer's service—depends critically on the capabilities of the local CO switch, and the customer's distance to it, rather than on the availability of fiber-optic trunk lines.[1] Digital technology, as yet, has not changed the overall architecture of the telephone system, and most new technology attempts to integrate data networks within the public switched telephone network (PSTN) (Allen 1999; Blumenstein 1999; Schoen et al. 1998).

A highly capable CO switch increasingly is part of office complexes and office parks, and room for wires and cables must be part of the buildings' architecture. The infrastructure of office buildings and complexes has become "an extension" of computer networks (Longcore and Rees 1996). The cost of a typical switch is over $1.4 million (Andrew and Kendall 1999).

A useful indicator of digital capability is the capability for integrated services digital network (ISDN), a technology is that is the benchmark against which newer technologies are commonly compared (Akimaru et al. 1997; Lu et al. 1998). To be upgraded to ISDN requires that digital CO switches be upgraded with electronic signaling equipment and ISDN software. The installation of SS7 software had been made in all BellSouth switches by 1997. However, ISDN capability was found in only 35.6% of BellSouth's switches by 1998, slightly higher than the 32.5% of switches of all companies in a recent report by the FCC (Rangos 1999). These served 66.8% of all BellSouth access lines, less than the 78.1% for all companies.

Also utilizing the copper infrastructure is xDSL, a family of digital subscriber line (DSL) technologies that provide high-speed data access. DSL services are considered the technology for residential and small business customers who are unable to get—or unable to afford the monthly cost of—a private T-1 line that by-passes the local telephone network. Newer modem technologies that permit transfer rates of 56 Kbps and DSL now compete with ISDN's 144 Kbps at far lower cost to the customer. The advantage of asymmetric DSL (ADSL) is that it transmits downstream (e.g. a Web page or video to the user) at much higher speeds (up to 8 Mbps) than upstream (e.g. a request for a link to Web page). DSL requires digital switching equipment, and is constrained to a short distance from the CO switch: 12,000-15,000 feet (less than 3 miles) from the CO. Very High Rate DSL (VDSL) provides faster speed (51.84 Mbps), but only within 1,000 feet of a switch, declining to 12.96 Mbps at 4,500 feet (i.e. less than one mile) from the switch (Bhagavath 1999; Northern Telecom 1998). Clearly, such distance-constrained technologies will be located at first in high-density neighborhoods, where early adopters are found (Carey 1999), and where a high density of business customers willing to pay for premium service are clustered.

Digitalization of CO switches took a while to become widespread. In 1990, less than 10% of the U.S. network was digital; by 1999, over 90% of all switches had digital stored program control and/or SS7 software, which enables a host of services (Rangos 1999: 6). The slow adoption of digital technology during the 1980s was attributed to investments in analog systems that were not yet amortized (Majumdar 1997). As a type of "modular technical change," digital switches can be added individually within a firm's network. Digital signaling permits the clear transmission of data and enables higher data rates, characteristics not possible in an analog system. Digital switches, combined with fiber-optic lines, also give rise to system-scale economies and network effects, reducing the cost of training, maintenance, and spare parts (Majumdar, 1997). Perhaps more significant than the cost savings is the capability to add value-added services such as custom-calling, which can bring a carrier additional revenue (Heldman, 1992). Much of the digitalization has been an "overlay" of digital remote switch units next to existing analog systems and connecting enabling software (SS7 signaling) to them. (Remote switches are dependent on a "host" switch or office). "In this manner, the switching system initially designed for the rural environment was being used for the more complex urban community, extending its product life cycle" (Heldman 1992: 155). Consequently, the term "digital switch" is misleading, according to Rangos (1999), because it does not address switching capability or modularity.

Investments in digital switches followed the patterns of radio, television, and basic telephone development—installed first in larger markets where the costs of their investments could be more easily realized, later moving to secondary and tertiary markets as the technology matured and costs declined (Egan 1996). In general, then, digital switches were implemented first in urban areas, where their greater capacity is most efficient and where business customers are most plentiful. Digital technology permits greater flexibility in the use of the resources of a telephone network (Banker et al. 1998). Such efficiency gains and revenue-generation potential typically are highest with business customers, especially large businesses, and their locations in metropolitan areas. The high cost per customer of rural remote switch units resulted in delay in full digitalization in rural areas.

In the monopolistic past, such business revenues were used as cross-subsidies to redress price imbalances that were involved in providing service to more rural service areas. With deregulation, many local service providers have found that it is not worth the expense to upgrade rural infrastructure. Such areas have low customer densities and few high-volume business customers to justify their investment. Farrell and Katz (1998) believe that current regulation works against incumbent firms, who are required to invest in rural portions of their service areas, while new firms (CLECs) can "cherry-pick" without this requirement.

Business communication demand is the driving force behind telecommunication investment, and are the telephone industry's cash cow. One of the correlates of digitalization is the proportion of business lines in a telco's total line mileage. In the years since deregulation, many entrenched telephone companies, primarily the "Baby Bells," have experienced significant decreases in business revenues due to new entrants in the telecommunications marketplace seeking to draw away ("cherry-pick") lucrative business contracts. The North Carolina Public Utilities Commission (1999), for example, reports that competitive local providers (CLPs) were providing service to 2.7% of the access lines in the state, but that these were predominantly (80.9%) lines serving business customers.

The Internet represents a break in the evolution of telecommunications (Kavassalis et al. 1996). The radically different method of networking represented by packet-switching poses huge challenges for the telephone network, within which the Internet largely developed. The infrastructure of the telephone system, particularly the central office (CO) switch, is a key piece in widespread Internet access (Schoen et al. 1998). A switch is needed even in wireless networks. The integration of Internet protocol (IP) into next-generation telecommunication networks, and of IP and telecommunications generally, is needed because remote access (via modem) will continue to be needed for many users, including both residential customers and small businesses.

The converged telecommunications infrastructure is moving toward IP in response to shifts in traffic from predominantly voice to predominantly data (Morgan 1998). However, it is unlikely that telecommunications infrastructure will ever be able to become all data (all IP). As in the past, the needs of large corporations suggest what the future will look like. For instance, call centers that large firms operate for both incoming and outgoing calls increasingly require a mix of voice and data capability, so that operators can access Internet data, or so that Web customers can receive customer service with a human being. CO switches are a critical piece of infrastructure for all dial-up users and small firms as well as the 200,000-plus corporate call centers in the U.S. Thus, Internet (IP) networks are only partially independent of the telephone network, and even firms that focus on providing by-pass service for large businesses must be connected to the telephone network.

4. Data

Studying the digitalization of American telecommunications is no easy task. The most accessible compilation is the biannual report of the FCC on *Infrastructure of the Local Operating Companies Aggregated to the Holding Company Level* (e.g. Rangos 1999). Majumdar (1995) studied the national data available through 1987, when the average penetration of digital switches was 56.16%. As with most FCC data, these data refer only to entire firms. There has generally not been at the federal level a requirement that firms disclose implementation of digital technology at individual locations within their systems, and even at the state level, aggregate firm-level data are considered to fall within the “trade secret” exemption to public records laws (NCUC 1999: 7).

However, Telcordia Technologies (formerly Bellcore—Bell Communications Research, Inc.) compiles and updates regularly a Local Exchange Routing Guide (LERG) for the entire U.S. We used this data set, dated February 1, 1998, which includes not only the specific CO switch by location, system manufacturer and product, but also 52 characteristics that define the features and functionality of each switch. In this report, we present a view of this data set for Kentucky, Mississippi, and North Carolina, update our work of a year ago for Tennessee, and attempt to draw conclusions about rural-urban differences in quality-of-service. We also present summary findings on several other dimensions of the switching fabric, as it is called, in the four states, including the presence of competitive providers (CLECs), of switches for wireless service, and of advanced packet switches. All switches in the LERG data were included, with the exception of those scheduled to be added or established later than February 1, 1998, and those scheduled to be modified after February 1, 1998. We did include switches scheduled to be deleted or replaced after that date. Thus, the switches analyzed are those in place in the region on February 1, 1998. We have no data on the location of customers connected to the switches.

Several of the functions and service indicators represent digital technology and lend themselves to analysis. We recognize that digital capability can be provided in either of two ways: customers distant from a switch could be connected by cabling (reinforced by signal repeaters and amplifiers) to a switch elsewhere, or by installing a digital “remote” switch nearer to those customers. This is a typical broadband topology (Heldman, 1992: 188). However, both of these options are expensive, and will not be implemented everywhere. In the data set studied, 884, or 43.8%, of the switches in the four states are labeled as remotes). We have no information on the implementation of repeaters and amplifiers. It is worth noting that few switches of CLECs are identified as remote switches.

CO switches are frequently co-located with other switches. Co-location permits a firm to upgrade older switches for existing lines, and co-location with competitive firms (CLECs) is a common, if grudging, practice permitted since the 1996 Telecommunications Act, and increasingly encouraged. In Manhattan, for example, as many as 20 switches are co-located at the same address. Co-location in Manhattan occurs mainly either among Bell Atlantic switches or among CLECs, rather than of CLEC switches at Bell locations.

The LERG data, by identifying the operator of a switch, can be used to analyze the degree to which new competitors (CLECs) are serving the market. The FCC (1998) survey provides a benchmark, with geographic breakdown only to the LATA level, bolstering the argument that large markets have seen the largest numbers of new competitors. Operators of a switch are considered "facilities-based," in contrast to CLECs that merely resell "unbundled network elements" of incumbent firms.

Data on the states and their counties were obtained from the U.S. Census Bureau Web site (www.census.gov), including 1998 population estimates, and the numbers of business establishments were taken from the County Business Patterns data for 1997.

5. A Comparison of Switch Provision in the Four States

A nationwide analysis allows us to place the four southeastern states into the national context. The four states contain 6.61% of all central office switches in the United States. Table 1 shows that the switch density, measured by land area per switch, is greatest in North Carolina, where a switch serves the smallest area, and sparsest in Mississippi. Both Kentucky and Tennessee, along with North Carolina, have a higher density of switches than the U.S. average. Population served per switch, as a state average, presents a different picture. On this basis, Kentucky and Mississippi are below the U.S. average of 8,856 people per switch, whereas North Carolina and Tennessee have higher values, both with over 10,000 people per switch, corresponding to the higher population density levels in these states. These higher population/switch values are more efficient from a provider's point of view, since more customers are linked to the average switch. In the four states, all counties have at least one switch, with the exception of one county in Mississippi, Issaquena County.

The four states in our study fall into two distinct groups: North Carolina and Tennessee have not only higher population densities but also more metropolitan populations. The switches in both states are nearly equally distributed between metropolitan (metro) and nonmetropolitan (nonmetro) areas, in sharp contrast to Mississippi and Kentucky, both of which have fewer than 30% of their switches in metro areas (Table 2). Table 2 suggests that nonmetro areas are relatively well-served by central office switches; the geographical distribution favors nonmetro counties. However, metro switches afford a provider greater efficiency, in terms of population/switch.

The number of local exchange companies (LECs)—telephone companies or telcos—reflects the degree of competition. Table 3 shows the number of telcos in each state, along with indicators of the smallest and largest of these.[2] Mississippi, the most rural of the four states, has the smallest number of LECs, the largest number of small firms with small rural service areas, and the highest degree of concentration of switches in the three largest firms. North Carolina is at the opposite end of the spectrum, with the smallest percentage of small LECs and the lowest degree of concentration in the three largest firms. Kentucky and Tennessee fall in between these two.

There are wide variations in the degree to which competitive local exchange carriers (CLECs) have entered the market in the four states. Table 4 indicates that only North Carolina, with over 15% of its switches belonging to CLECs, is above the U.S. average for CLEC penetration, as measured by number of switches belonging to CLECs. Kentucky and Mississippi, with 5.8% and 8.6%, respectively, have the fewest CLECs as well as the fewest CLEC switches. Tennessee falls below North Carolina and the U.S. average, but ahead of Kentucky and Mississippi.

6. Levels of Service of Central Office Switches

The principal focus of this report is the capability of CO switches. For this purpose, we have proposed a hierarchy that represents an increasing degree of digital capability. The lowest level switch is one that does not have the capability for international direct dialing. A Level 1 switch provides this capability. Level 2 switches have implemented Signaling System 7, the software fundamental to popular customer services, such as call-waiting and caller-ID, and to all advanced digital services. Level 3 is the lowest data-oriented capability, providing 56Kbps data transmission. Level 4 is any of three implementations of primary-rate interface (PRI) ISDN. Level 5 is multi-rate ISDN. Table 5 defines these levels in detail.

Utilizing this hierarchy, the switching fabric in the four southeastern states was determined, as shown in Table 6 and Figure 1. The table and accompanying graph illustrate once again the tremendous variation in the region. North Carolina has the largest percentage of both Level 0 and Level 3 switches. Kentucky has the largest percentage of Level 2 switches and the lowest level of advanced capability. Tennessee has the largest number of both Level 4 and Level 5 switches. Mississippi has both the largest percentage of Level 1 and the second-highest percentage of Level 4 switches. The policies and investments of the dozens of LECs in each state, and the regulatory situation of each state, are the causes of the variation evident among the four states.

The urban-rural or metro-nonmetro distribution of switches provides greater insight into the implementation of digital technology by telecommunications providers in the region. For this purpose as well, we group the levels of switch capability into two: basic (Levels 0, 1 and 2), intended mainly for voice and analog transmission, and advanced (Levels 3, 4 and 5), intended mainly for data transmission. When aggregated in this way, (shown in Table 7) two trends become prominent: that urban areas are the principal locations for advanced switches in Kentucky, Mississippi, and Tennessee, and that both North Carolina and Tennessee have relatively high levels of capability in rural locations. North Carolina stands out as having the highest percentage (35.9%) of advanced switches in rural areas. Several of the LECs serving rural areas of North Carolina, most notably Sprint Mid-Atlantic, have installed switched 56Kbps (Level 3) capability in many of their switches in rural locations.

The pattern in the four states is summarized in Table 8, which shows the significantly different capability of urban and rural counties in the four states. While it is clear that Levels 0, 1 and 2 switches, with minimal capability, are mainly found in nonmetro counties, the number of high-capability switches (Levels 3, 4 and 5) in nonmetro counties (34.8% of nonmetro counties) is surprising. The metro counties without high-level switch capability are generally those in the less-dense suburban fringe of metropolitan areas.

Packet Switches

Two dimensions of the evolving telecommunications infrastructure warrant attention. The highest-level digital switch, the *packet gateway switch* (X75 protocol), is used for the growing volume of data traffic through the switched network. Just under 1% of all switches in the United States are capable of packet gateway function. Of the 48 coterminous states, 43 have at least one packet gateway; the median number in a state is four. North Carolina is one of ten states with 5 packet gateway switches, placing it in the upper 50% of states. Tennessee is one of six states with 4 packet gateways; Kentucky and Mississippi are among four states with 3.[3] As in most states, these switches are relatively evenly distributed throughout a state with rather large territories as implicit or explicit service areas.

More widespread are *packet switches*, which use either X121 or E164 addresses to provide intra-LATA packet data access. These fall somewhere between our Levels 4 and 5 switches in frequency, but are not tied to ISDN technology. Only 480 (1.6%) of all U.S. switches have Level 5 capability, whereas 2,903 (9.5%) are packet switches. In the four states studied here, 222 are packet switches, 63% of which are in Tennessee alone

(Table 9). In both Tennessee and Mississippi, a greater percentage of packet switches are in rural locations than is the population. North Carolina has by far the most urban concentration of packet switching (over 89%), and the fewest rural switches with packet capability. Recall, however, from Table 7 that North Carolina has by far the greatest number of advanced switches (most of them Level 3) in rural counties of any of the four states.

Packet switches are concentrated in the largest urban areas. Nashville is one the leading large MSAs in the country in the share of packet switches, with 35 or 44% of all switches in 32 locations. Knoxville has 18 in 14 locations and Memphis has 18 in 15 locations; Chattanooga has 11 in eight locations. In Kentucky, Louisville has 11 in nine locations. In North Carolina, Charlotte MSA has 19 in 12 locations, Raleigh-Durham has 14 in 11 locations; Greensboro–Winston-Salem–High Point has 15 in 10 locations.

Although Jackson has only five packet switches in three locations, packet switches are well distributed throughout Mississippi, including in 14 nonmetro counties as well as the Gulfport and Jackson MSAs. Moreover, they belong to eight different LECs, including three CLECs. In Kentucky, North Carolina and Tennessee, packet switches are only those of BellSouth.

Co-Location: Switch Clusters

Co-location of switches allows several to share access to trunk lines, and permits modular upgrades, effectively eliminating low capability, by allowing a higher-functionality switch to provide the higher level of service to less capable systems. In urban areas, packet switches are typically co-located with other advanced switches in what can be thought of as “super-switch” clusters. Such super-switch clusters are an increasingly common way to implement advanced digital services, such as ADSL, simultaneously with voice telephone service (Bhagavath 1999, Figures 3-5).

The four states have many co-location switch clusters. Kentucky's 482 switches are located at 418 sites; 64 switches are co-located at 37 sites: in 25 clusters in rural counties and in 12 urban clusters, the largest of which are clusters of seven switches in both Lexington and Louisville. Among rural clusters is a super-switch cluster in Madisonville. In Kentucky, all but one of the Level 0 (no IDDD) switches is co-located with a switch that provides that capability.

In Tennessee, 117 switches are co-located in 37 clusters: 23 in urban areas and 14 in rural areas. Clusters of co-located switches include one of eight switches in Chattanooga, clusters of eight and six in Nashville, of nine and four in Knoxville, one of seven and three of three in Memphis, of three in Bristol and Jackson, and 14 other clusters of two or three switches. Nonmetro clusters include one of four switches in Chapel Hill and one of three in Cookeville, and 12 rural locations of two co-located switches.

In Mississippi, there are 26 switch clusters, containing 69 switches: 14 in metro areas and 12 in rural counties. The largest is a super-switch cluster in Jackson, with six switches. The only other cluster with more than three switches is a 4-switch cluster in Hattiesburg. The other 12 urban and all 12 rural clusters have either two or three switches, negating except for a switch in Byhalia the presence of Level 0 capability.

In North Carolina, there 64 clusters containing 213 switches: 51 switch clusters in metro areas and 13 clusters of two or three switches in rural areas. The metro clusters include super-switch clusters of 11 and of six switches in Greensboro, clusters of 11 and of five switches in Charlotte, an 8-switch cluster in Asheville, one of seven in Raleigh, one of six in Durham, and clusters of five switches in Rocky Mount and Wilmington. The implication of these concentrations is that only customers (residential or small business) located within about two miles of a super-switch are able to enjoy the growing suite of broadband services.

Wireless Switches

Switches for wireless (cellular or PCS) telephone service are a growing part of the telecommunications system. In the four states, 150 (7.4%) of the 2,017 CO switches are for wireless service. These switches are primarily for voice communication and rarely have digital capability; newer switches may have come into the region since early 1998, the date of the data analyzed here.

Wireless service is the common entry niche of CLECs. Nationwide, 10% of switches are for wireless service, and these rarely have the levels of digital capability found in wire-based switches. In the four states, only North Carolina attains the national figure (Table 10). Once again, North Carolina and Tennessee have wireless service to a greater degree in rural areas than do Kentucky and Mississippi, where there are few rural wireless switches—fewer than the rural distribution of population.

As an example, there are 28 switches for wireless service in Kentucky, 21 of them in metro counties: five (four different telcos) in the Huntington-Ashland MSA, 10 (eight telcos) in the Lexington MSA, and six (five telcos) in the Louisville MSA. Six telcos have seven switches for wireless service in rural locations: Harold, two in Elizabethtown (south of Louisville), Madisonville, Pittsburg, Somerset, and Morehead. Generally, in Kentucky and Mississippi, wireless switches fail to serve much of the rural population (Table 10).

In Tennessee, 21 of 27 wireless switches are in six of the state's metro areas: five in both the Knoxville and Nashville MSAs, four in the Memphis MSA, three in the Chattanooga and Johnson City–Kingsport–Bristol MSAs, and one in the Jackson MSA. The six nonmetro wireless switches are in Cookeville, Lawrenceburg, Monterey, Morristown, Smithville, and Winchester. Thus, 77.8% of the state's wireless switches are in metro areas, more than the 67.6% of the state's population found in them.

In Mississippi, eight of the 19 wireless switches are in the Jackson MSA; three others are found in Gulfport and one in Hattiesburg. Seven wireless switches are located in rural counties: in De Kalb, Lynville, two in Greenwood, Artesia, Iuka, and Tishomingo. Only Greenwood has competition; one of its two wireless providers is a CLEC.

The Effect of Competitive Telecommunications on the Southeastern States

Wireless service is tied to the story of competition in telecommunications and the uneven emergence of CLECs. By and large, new competitive providers have targeted the urban markets for service. In North Carolina, 12 firms provide wireless service in metro areas, compared with only seven in nonmetro counties. Overall, competing local providers (CLPs) in North Carolina have been overwhelmingly urban in focus. The North Carolina Utilities Commission (1999) reports that 17 of 26 reporting companies granted CLP status as of July 15, 1999 were providing service to 108,815 businesses and 25,744 residential customers—a ratio favoring businesses by over 4:1. The absence of competition in rural counties can be responsible for lower levels of service, compounded by rural characteristics of low customer density and few business customers.

Table 10 shows the penetration by CLECs in the switching fabric of the four states. Generally, CLECs are most present in metro areas, and consequently, most metro counties have some competition in telephone service. Between one-sixth and over one-quarter of all CLEC switches are found in metro counties in the four states, but no more than 4% of all rural switches belong to CLECs, with the highest percentage in Kentucky (Table 11).

In Kentucky, eight of nine CLEC nonwireless switches are in metro areas (six at four sites in Louisville, two in Lexington), and one is in Paducah. (An additional three were scheduled to be established later in 1998, two of them in nonmetro locations: Bowling Green and Madisonville, in addition to one more in Louisville.) One CLEC switch, ALEC's in Paducah, offers Level 5 capability. The other two Level 5 switches in Kentucky are also in rural locations: BellSouth switches in Prestonsburg and Paintsville in eastern Kentucky.

The overall picture in the Southeast, then, is one of tremendous variation—variation across states and variation within the four states being studied. The next section attempts to understand both the patterns within each state and the differences among the states in the project study area.

7. What Accounts for the Variation in Telephone Switch Capability?

Co-location and the specific capabilities of a given switch make it somewhat difficult to capture the level of service possible across an entire area. In the absence of exact data on the area-of-service of each switch, aggregating switches by county allows for some analysis of switch capability at the county level.

Level of Capability: Number of Switches in a County

The number of switches increases with population, but more steeply in Mississippi and less steeply in Kentucky and Tennessee (Figure 2). However, the situation is more complex than one of population alone. We use a model of the form

$$Sw_i = a + bX_i,$$

where Sw_i = the number of switches in a county, and X_i = one or more of four independent variables: county population, the total number of business establishments in a county, the number of business establishments with employment of 100 or more, and the number of business establishments in business services (SIC 73).[4] Table 12 presents the results for the 397 counties combined. It shows that the number of switches in a county increases with each of the variables, but that the total number of business establishments in a county is the best single predictor of the number of CO switches. Population density is the least effective predictor of the number of switches. However, when analyzed in combination with the total number of business establishments, the other variables take on a negative sign and/or are statistically insignificant.

Disaggregating the region into the individual states, Table 13 shows that, in all four states, the total number of business establishments in a county better accounts for the number of phone switches than does population. The difference is slight in the case of Kentucky. Mississippi, with its switch distribution the least well-explained by population and business establishments, has its pattern most accounted for by the number of business service establishments (SIC 73).

Metropolitan areas, with their agglomerations of business and residential customers, are more easily accounted for with measures of those markets. Table 14 shows that the number of switches in a county is much better-explained (indicated by the higher adjusted R^2 values) for metro counties than for nonmetro counties. However, population is generally a better predictor of the number of switches in rural counties, whereas the total number of business establishments generally better predicts the number of switches in metro counties. The presence of population and, even more, of business customers, explains no less than 83% and as much as 95% of the variance in the number of metro-area switches. Explaining the pattern in the 305 rural counties is less effective, with levels of explanation (adjusted R^2 values) much lower—between 20% and 45%. Switches in Mississippi and Tennessee are the least well-accounted for by the model used here; North Carolina is the best explained.

Level of Capability: Highest Level of Switch in a County

The hierarchy of switch capability addresses the need for information beyond the declaration by telcos that their switches are “digital.” Although each switch has its own unique capability, they also can be aggregated by county to characterize the highest switch level in a county. A series of graphs (Figures 3-6) illustrates the trend of higher capability among switches in metropolitan areas, but also shows that this trend is not absolute. Kentucky, for instance, has several Level 5 switches in rural counties, including Paducah, the site of the Paducah Information Age Park (Lyons 1997). In general, in all four states, the lowest levels of capability are in the least populated counties. North Carolina and Tennessee, with their large urban areas and preponderance of Level 5 switches in those areas, reinforce the generalization that higher levels of digital capability are found in urban areas.

Table 15 presents detailed summaries of the variation in switch level by state. It is clear that the expected hierarchical pattern—that higher levels of switch capability would be tend to be found in larger counties and in metropolitan counties—does not apply across the board in the four states. Taking the states in turn, Kentucky comes close to the expected pattern, with the notable exception of Level 5 switches, which are found only in rural counties. As a result, mean county population, mean number of switches per county, and mean population per switch, all increase steadily through Level 4 and then decline. In Mississippi, mean county population and the mean number of switches per county increase as expected, but the preponderance of nonmetro counties have switches without digital capability.

Attempting to account statistically for the level of switch capability, we estimated a model in which the highest switch level in a county is a function of the total number of business establishments in the county, county population, Beale code[5], and population density. The results (Table 16) show that, although all four variables are related to switch level, the level of capability is best accounted for by increasing county population and a lower Beale code or more urban status on the rural-urban continuum.

Separating the metro and nonmetro counties in the four states (Table 17), county population provides the best single-variable explanation of county switch, with higher levels of explanation for urban (metro) counties. For both types, the best model is one that combines county population with population density. For metro counties, density is a negative factor, reducing the highest county switch level, but this variable enters at a lower level of significance. For nonmetro counties, increased density contributes to a higher level of switch capability in a county. However, no more than one-quarter of the variance is explained by the model for metro counties, and barely 15% for nonmetro counties, reflecting the wide variation in the region.

8. Conclusions and Implications for Rural Residents

Increasingly, digital communications is a "must" for doing business, whether for large firms or for entrepreneurs, and has become an ordinary part of daily life for many people. The availability of high-speed and broadband technologies can determine the services firms are able to offer their customers. The quality of rural jobs depends to a great extent on rural America having access to the same communications technology as the rest of the nation.

This research has documented the inequality in telecommunications level-of-service for four southeastern states in the TVA region. Using a hierarchy for level-of-service, the highest-capability switches are concentrated disproportionately in metropolitan areas, largely in response to larger populations and larger concentrations of businesses. Although we had expected the location of business services (SIC 73) to be a strong influence on CO switch capability, this proved to be less significant than more general agglomeration factors, such as population or the total number of business establishments.

Rural (nonmetro) counties are more likely to have both fewer switches and switches with lower levels of digital capability. However, this generalization applies best to North Carolina and Tennessee, the two states of the four studied that are most urbanized. These two states also have seen the greatest entry by new telecommunications competitors (CLECs). These two states have the largest percentages of advanced (digital) switches in both metro and rural counties (Table 7). In Kentucky and Mississippi, there are small areas with high levels of digital switch capability, but these are not widespread.

This research provides new insights into understanding differences in level-of-service, especially in new digital technologies. While our hierarchy of switch capability is not perfect, it sheds considerable light on the nature of technological change in the telecommunications industry under deregulation, and on the geographical disparities that are evolving. On the whole, it is residents of metropolitan—not rural—areas who are most likely to be served by higher levels of digital telecommunications.

Endnotes

[1] The FCC's Kraushaar (1999: 26) notes that "it does not appear that there is much investment directed toward fiber facilities associated with access to smaller customers."

[2] The LEC or operating company as recorded in the LERG data is an overstatement. Large companies, such as BellSouth and other RBOCs, GTE, and others that operate across state lines, tend to register as separate entities in each state. For example, GTE in North Carolina and GTE in Tennessee are recorded as two LECs. The same is true of many CLECs, including wireless service providers.

[3] Seven states had more than ten packet gateway switches in early 1998: Washington (43), Ohio (26), Minnesota (24), Colorado (23), Texas (22), Nebraska (14), and Arizona (12).

[4] The data on county population for 1998 were taken from the U.S. Bureau of the Census Web site <http://www.census.gov/population/www/estimates/co_98_2.html>. The total number of business establishments and establishments in business services (SIC 73), and employment size of establishments (from which the number of establishments with employment 100 or more were calculated) were taken from County Business Patterns. <http://www.census.gov/pub/epcd/cbp/download/dwncbp97.html>.

[5] The rural-urban continuum codes are: Metro counties: 0 - Central counties of metro areas of 1 million population or more, 1 - Fringe counties of metro areas of 1 million population or more, 2 - Counties in metro areas of 250,000 to 1 million population, 3 - Counties in metro areas of fewer than 250,000 population; Nonmetro counties: 4 - Urban population of 20,000 or more, adjacent to a metro area, 5 - Urban population of 20,000 or more, not adjacent to a metro area, 6 - Urban population of 2,500 to 19,999, adjacent to a metro area, 7 - Urban population of 2,500 to 19,999, not adjacent to a metro area, 8 - Completely rural or less than 2,500 urban population, adjacent to a metro area, 9 - Completely rural or less than 2,500 urban population, not adjacent to a metro area. These are available on the ERS Web site <http://www.ers.usda.gov/epubs/other/typolog>

Table 1: Density of Central Office Switches by State (ranked by land area/switch)

State	Total CO switches	Land area (sq. mi.)/switch	Population/ switch	Population density (per sq. mi.)
North Carolina	719	73.3	10,496	141
Kentucky	482	81.6	8,167	97
Tennessee	490	83.6	11,083	130
Mississippi	326	142.6	8,442	58
United States	30,521	124.1	8,856	76

Table 2: Nonmetro and Metro Locations of CO Switches by State

State	Nonmetro switches	% Nonmetro switches	Metro switches	% Metro switches	% of state population in metro areas*
Kentucky	347	72.0%	135	28.0%	48.3%
Mississippi	258	79.1%	68	20.9%	35.0%
North Carolina	365	50.8%	354	49.2 %	66.6%
Tennessee	251	51.2%	239	48.8 %	67.8%
U.S. average		46.8%		53.2%	79.8%

* Source: U.S. Census Bureau (1998) *Statistical Abstract of the United States*, p. 40.
<http://www.census.gov/prod/3/98pubs/98statab/sasec1.pdf>

Table 3: Distribution of Switches by LEC

State	Number of Local Exchange Companies	% of LECs with fewer than 5 CO switches	% of switches belonging to top three LECs in state
Kentucky	40	58%	66%
Mississippi	33	82%	78%
North Carolina	50	54%	56%
Tennessee	51	66%	59%

Table 4: CLEC Penetration by State

State	Number of CLECs with switches	CLECs as % of all LECs	Number (and percentage) of switches belonging to CLECs
Kentucky	18	45.0%	28 (5.8%)
Mississippi	14	42.4%	28 (8.6%)
North Carolina	25	50.0%	110 (15.3%)
Tennessee	22	43.1%	56 (11.4%)
United States	670	32.1%	3884 (12.7%)

Table 5: A Hierarchy of Switch Capability

Switch Level	
0	No Advanced Services
1	International Direct Dial: switch provides direct dialing for international calling
2	SS7: switch with Signaling System 7
3	Switched 56K ISDN: a switched 56Kbps service, generically known as public switched digital service (PSDS), providing the end user (customer) with the ability to send and receive data at a speed of 56Kbps over the public switched network utilizing in-band signaling.
4	Either: (a) PRI 64: an ISDN Primary Rate Interface (PRI) access capability that allows a customer premise device to communicate directly with the network and/or another ISDN-equipped location, utilizing an out-of-band protocol and has data rates of 56Kbps, 64Kbps clear, or multiple combinations of 56 OR 64Kbps clear. PRI is 23 64Kbps bearer channels, which can be used for any combination of voice and data, and one 64Kbps data channel that is used for signaling (23B+D). (b) BCR6: an ISDN Basic Rate Interface (BRI) access capability that allows a customer premise device to communicate directly with the network and/or another ISDN-equipped location utilizing an out-of-band signaling protocol and has data rates of 56Kbps OR 64Kbps clear. BRI is two bearer channels, which can be used for voice and data, and one data channel that is used for signaling (2B+D). (c) BCR5: an ISDN basic rate interface (BRI) access capability that allows a customer premise device to communicate directly with the network and/or another ISDN-equipped location utilizing an out-of-band signaling protocol and has a data rate of 56Kbps.
5	Multi-Rate ISDN: A circuit switched service that allows customers to set up n x 64Kbps (n by 64) calls from an ISDN (Primary Rate Interface circuit in real time and in the same manner as any circuit-switched ISDN call. ISDN Multirate is an extension of the 64Kbps service offering in that it can set up a call from 64Kbps to 1,536Kbps (1 DS0 TO 24 DS0s) in bandwidth capacity.

Table 6: Distribution of Switches in the Four Southeastern States by Level of Capability

	Switch Level					
	0	1	2	3	4	5
Kentucky	1.2%	41.7%	47.9%	2.1%	6.4%	0.6%
Mississippi	4.0%	51.8%	35.9%	0.0%	8.3%	0.0%
North Carolina	7.5%	44.9%	13.5%	25.3%	8.2%	0.6%
Tennessee	3.3%	25.1%	37.1%	8.8%	23.9%	1.8%

Table 7: Switch Capability in the Four States, by Urban and Rural Location

	Urban (metro) switches		Rural (nonmetro) switches	
State	Basic: Levels 0, 1 & 2	Advanced: Levels 3, 4 & 5	Basic: Levels 0, 1 & 2	Advanced: Levels 3, 4 & 5
Kentucky	79.3%	20.7%	95.4%	4.6%
Mississippi	73.5%	26.5%	96.5%	3.5%
North Carolina	67.8%	32.2%	64.1%	35.9%
Tennessee	54.0%	46.0%	76.1%	23.9%

Table 8: Highest Level of Switch Capability by Category, Metro and Nonmetro Counties

	Metro counties	Nonmetro counties
Level 0, 1, or 2	27	200
Level 3, 4, or 5	63	107

Table 9: Packet Switches in the Four States, by Urban and Rural Location

	Number of packet switch locations (and switches)	Packet switches in urban counties (%)	Packet switches in rural counties (%)	% of population in rural counties
Kentucky	21 (27)	11 (52.4%)	10 (47.6%)	51.7%
Mississippi	23 (24)	5 (21.7%)	18 (78.3%)	65.0%
North Carolina	38 (54)	34 (89.5%)	4 (10.5%)	33.4%
Tennessee	140 (153)	76 (54.3%)	64 (45.7%)	32.2%

Table 10: Rural Location of Wireless Switches

	Wireless switches (% of state total)	Nonmetro wireless switches (% of wireless total)	Nonmetro population as % of state total	Difference between nonmetro share of population and share of switches
Kentucky	28 (5.8%)	7 (25.0%)	51.7%	26.7
Mississippi	19 (5.8%)	7 (36.8%)	64.1%	27.3
North Carolina	75 (10.4%)	16 (21.3%)	32.9%	11.6
Tennessee	28 (5.7%)	6 (22.2%)	32.4%	10.2

Table 11: CLEC Switches in the Southeastern States

	CLEC switches (% of all switches)	CLECs with Metro switches	CLEC switches in metro areas (% of all)	CLECs with rural switches	CLEC switches in rural counties (% of all)
Kentucky	28 (5.8%)	17	23 (16.5%)	5	5 (3.6%)
Mississippi	28 (8.6%)	13	21 (25.6%)	4	7 (2.9%)
North Carolina	107 (14.9%)	24	98 (23.3%)	4	9 (3.1%)
Tennessee	56 (11.4%)	21	50 (20.4%)	5	6 (2.4%)

Table 12: Explanation of Variation in Number of Switches in a County, Four States Combined

Model	Constant	Adjusted R^2	County population	Population density	Total business establishments	Business establishments with 100+ Employment	Business service establishments (SIC 73)
1	1.841	.790	0.0000656 (38.60)				
2	1.987	.602		0.0308 (24.50)			
3	2.466	.828			0.002188 (43.67)		
4	2.969	.796				0.0683 (39.29)	
5	3.443	.773					0.0286 (36.77)
6	1.896	.790	0.0000705 (18.88)	-0.00291 (1.45)			
7	2.611	.830	0.0000019 (0.244)	-0.004545 (2.51)	0.00237 (9.61)		
8	2.093	.832			0.003247 (8.74)	-0.008696 (0.96)	-0.010885 (3.18)
9	2.306	.841	-0.0000192 (2.23)	-0.007669 (4.09)	0.004872 (8.67)	-0.002238 (0.25)	-0.02194 (5.27)

Numbers in parentheses are t-values; values greater than 2.0 are statistically significant.

Table 13: Factors Accounting for the Number of Phone Switches in a County

	County population	Total business establishments	Business establishments with 100+ employment	Business services establishments (SIC 73)
Kentucky	Constant = 2.145 0.0000583 (18.03) Adj R^2 = .733	Constant = 2.593 0.00197 (18.32) Adj R^2 = .738	Constant = 2.947 0.05802 (16.86) Adj R^2 = .704	Constant = 3.150 0.0291 (16.46) Adj R^2 = .694
Mississippi	Constant = 0.914 0.0000919 (12.13) Adj R^2 = .646	Constant = 1.346 0.00367 (13.44) Adj R^2 = .689	Constant = 1.640 0.1385 (14.00) Adj R^2 = .706	Constant = 2.180 0.0734 (14.35) Adj R^2 = .717
North Carolina	Constant = 1.613 0.0000732 (21.26) Adj R^2 = .822	Constant = 2.841 0.00218 (23.27) Adj R^2 = .845	Constant = 3.545 0.07226 (22.31) Adj R^2 = .834	Constant = 4.496 0.02514 (19.32) Adj R^2 = .790
Tennessee	Constant = 1.871 0.0000596 (22.11) Adj R^2 = .838	Constant = 2.214 0.00216 (30.39) Adj R^2 = .908	Constant = 2.704 0.06430 (25.81) Adj R^2 = .876	Constant =2.991 0.03161 (28.20) Adj R^2=.894

Numbers in parentheses are t-values; values greater than 2.0 are statistically significant.

Table 14: Effect of County Population and Business Establishments on Number of Switches

	Nonmetro counties only		Metro counties only	
	County population	Total business establishments	County population	Total business establishments
Kentucky (22 metro; 98 nonmetro counties)	Constant = 1.4142 0.000101 (8.23) Adj R^2=.413	Constant = 2.0589 0.003561 (7.29) Adj R^2 = .350	Constant = 1.4260 0.0000582 (11.88) Adj R^2 = .870	Constant = 2.1240 0.00195 (13.57) Adj R^2 = .897
Mississippi (9 metro; 73 nonmetro counties)	Constant = 1.5856 0.000727 (4.74) Adj R^2 = .230	Constant = 2.1224 0.00243 (4.38) Adj R^2 = .202	Constant = -5.5879 0.000136 (6.44) Adj R^2 = .835	Constant = -3.3433 0.005038 (10.11) Adj R^2 = .927
North Carolina (35 metro; 65 nonmetro counties)	Int = 2.000 0.000066 (7.28) Adj R^2 = .448	Int = 2.742 0.09500 (7.04) Adj R^2 = .431	Int = 1.1726 0.0000749 (11.81) Adj R^2 = .803	Int = 4.5952 0.06898 (13.05) Adj R^2 = .833
Tennesseee (26 metro; 69 nonmetro counties)	Int = 2.0062 0.0000605 (4.24) Adj R^2 = .200	Int = 2.2857 0.002527 (4.36) Adj R^2 = .209	Int = 1.3093 0.0000645 (6.44) Adj R^2 = .875	Int = 1.2785 0.00223 (10.11) Adj R^2 = .952

Numbers in parentheses are t-values; values greater than 2.0 are statistically significant.

Table 15: Characteristics of Counties by Highest Switch Level, by State

State	Highest switch level	Number of counties	Mean county population	Metro/ non-metro counties	Number of switches	Mean number of switches per county	Mean population per switch
Kentucky	1	17	13,891	0 / 17	48	2.8	4,920
	2	85	22,143	14 / 71	259	3.0	7,267
	3	3	112,300	2 / 1	34	11.3	9,909
	4	12	112,459	6 / 6	123	10.3	10,972
	5	3	43,941	0 / 3	23	7.7	5,731
Mississippi	0	1	1,629	0 / 17	0	0	–
	1	19	20,559	0 / 19	32	1.7	12,207
	2	43	30,029	3 / 40	162	3.7	7,971
	3	0	–	–	–	–	–
	4	19	56,243	4 / 15	134	7.1	7,975
	5	0	–	–	–	–	–
North Carolina	1	15	33,733	3 / 12	64	4.3	7,906
	2	16	53,103	6 / 10	83	5.2	10,237
	3	50	47,214	11 / 39	256	5.1	9,220
	4	14	125,281	10 / 4	140	10.0	12,528
	5	5	415,245	5 / 0	171	34.2	12,142
Tennessee	1	6	20,159	0 / 6	17	2.8	7,115
	2	25	16,070	1 / 24	80	3.2	5,022
	3	9	59,598	4 / 5	27	3.0	19,866
	4	51	51,654	18 / 33	227	4.5	11,605
	5	4	430,960	3 / 1	121	30.2	14,247

Table 16: Factors Explaining Variation in Highest Level of Switch Capability by County, Four States Combined

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	2.389	2.322	3.642	2.333	3.120	3.064
Total Business Establishments	0.000169 (8.71)				0.00000941 (0.10)	
County Population		0.00000545 (9.26)			0.00000474 (1.53)	0.00000374 (5.56)
Beale Code			-0.17723 (8.80)		-0.11649 (4.82)	-0.11082 (4.86)
Population Density				0.00257 (7.92)	-0000829 (1.19)	
Adjusted R^2	.161	.176	.162	.135	.220	.221

Numbers in parentheses are t-values; values greater than 2.0 are statistically significant.

Table 17: Factors Explaining Variation in Highest Level of Switch Capability by County, all Four States, by Metro/Nonmetro Status

Variable	Model 1		Model 2		Model 3	Model 4	
	Metro	Nonmetro	Metro	Nonmetro	Nonmetro	Metro	Nonmetro
Constant	2.896	1.978	2.817	1.870	4.115	2.969	1.795
Total Business Establishments	0.000109 (5.44)	0.000742 (6.92)					
County Population			0.0000035 (5.49)	0.0000197 (7.12)		0.0000052 (4.22)	0.0000126 (2.92)
Beale Code					-0.24235 (5.88)		
Population Density						-0.001089 (1.61)	0.004626 (2.15)
Adjusted R^2	.239	.134	.243	.141	.100	.256	.151

Numbers in parentheses are t-values; values greater than 2.0 are statistically significant.

Figure 1. Capability of Switches in Four Southeastern States

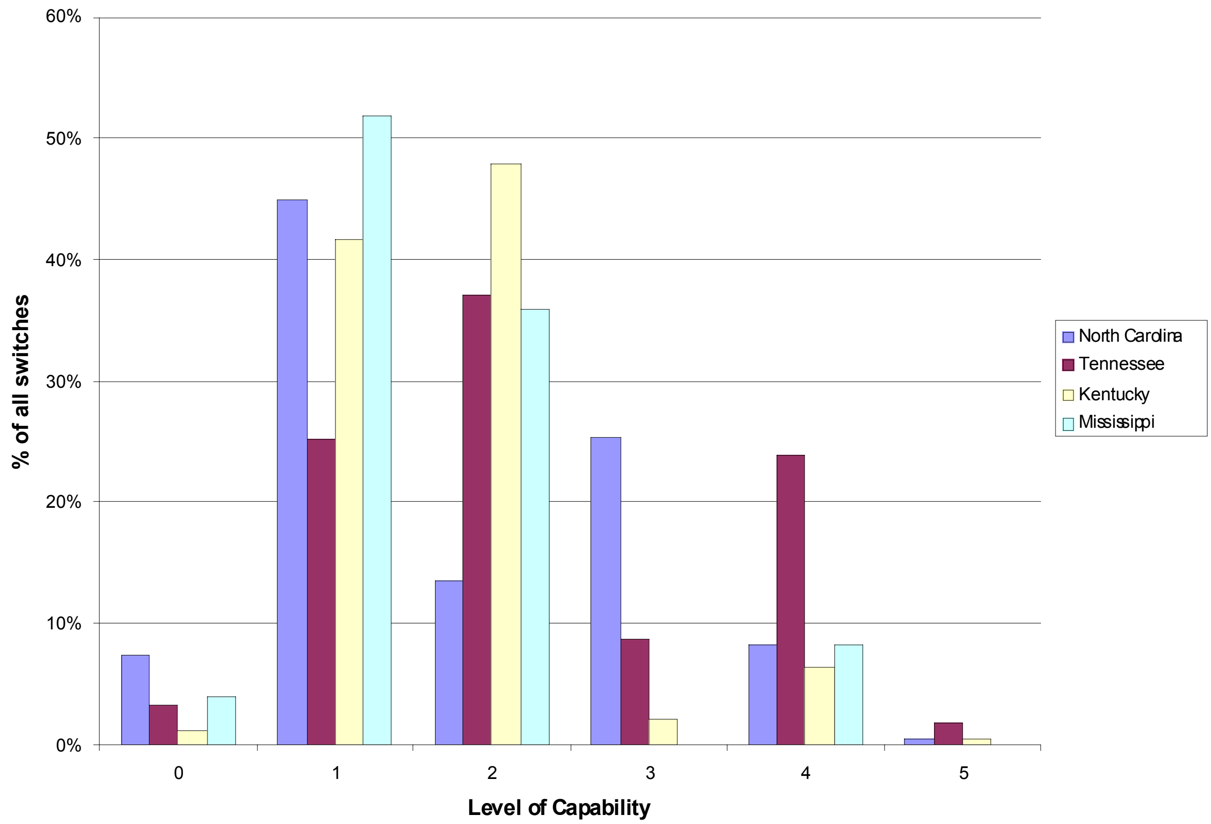


Figure 2. Number of CO Switches and County Population: Four TVA Region States

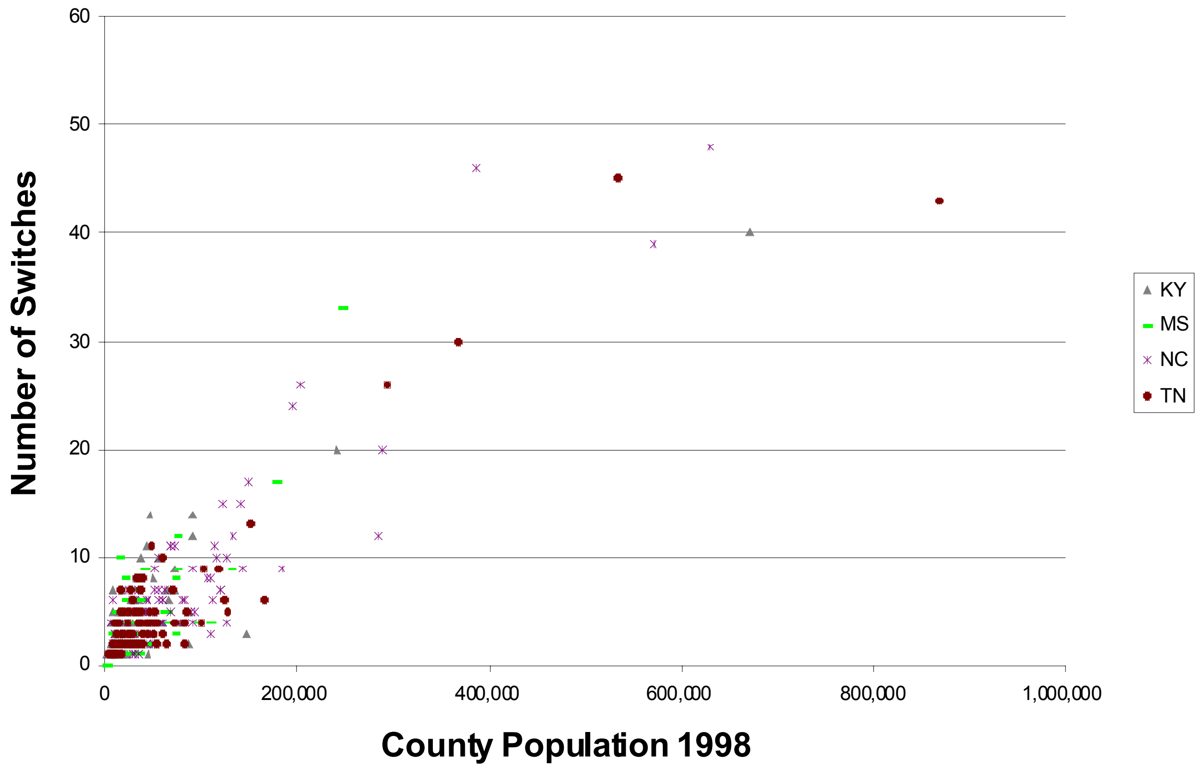


Figure 3. Average Population by Switch Level: KY

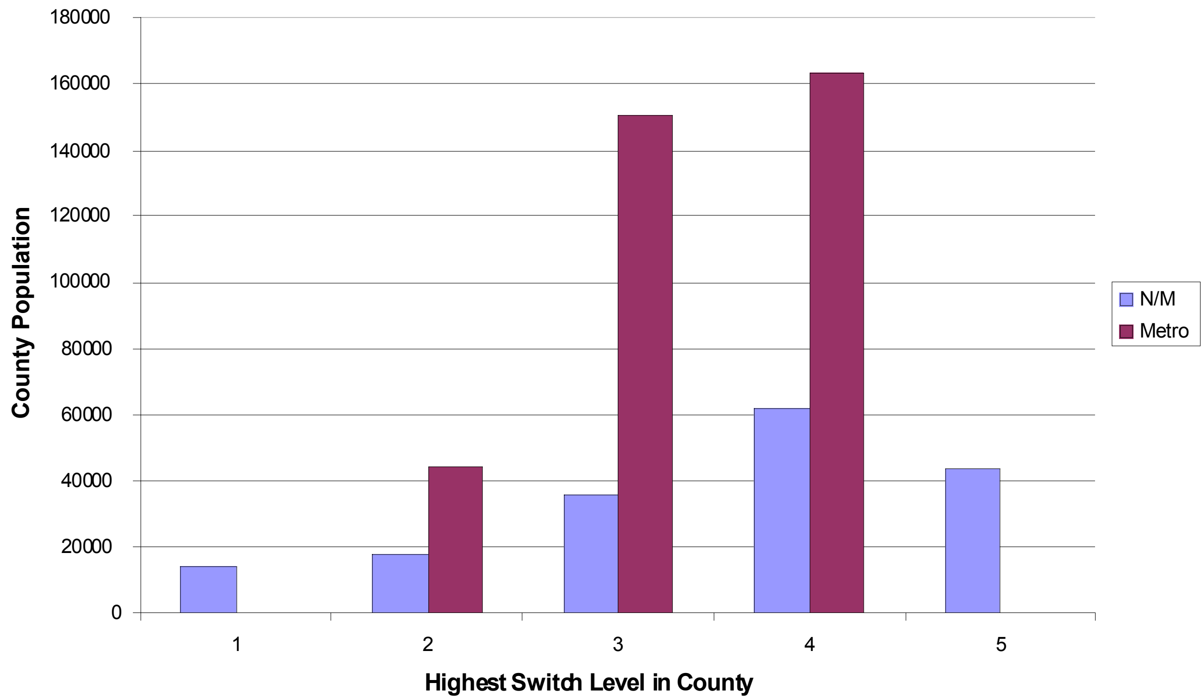
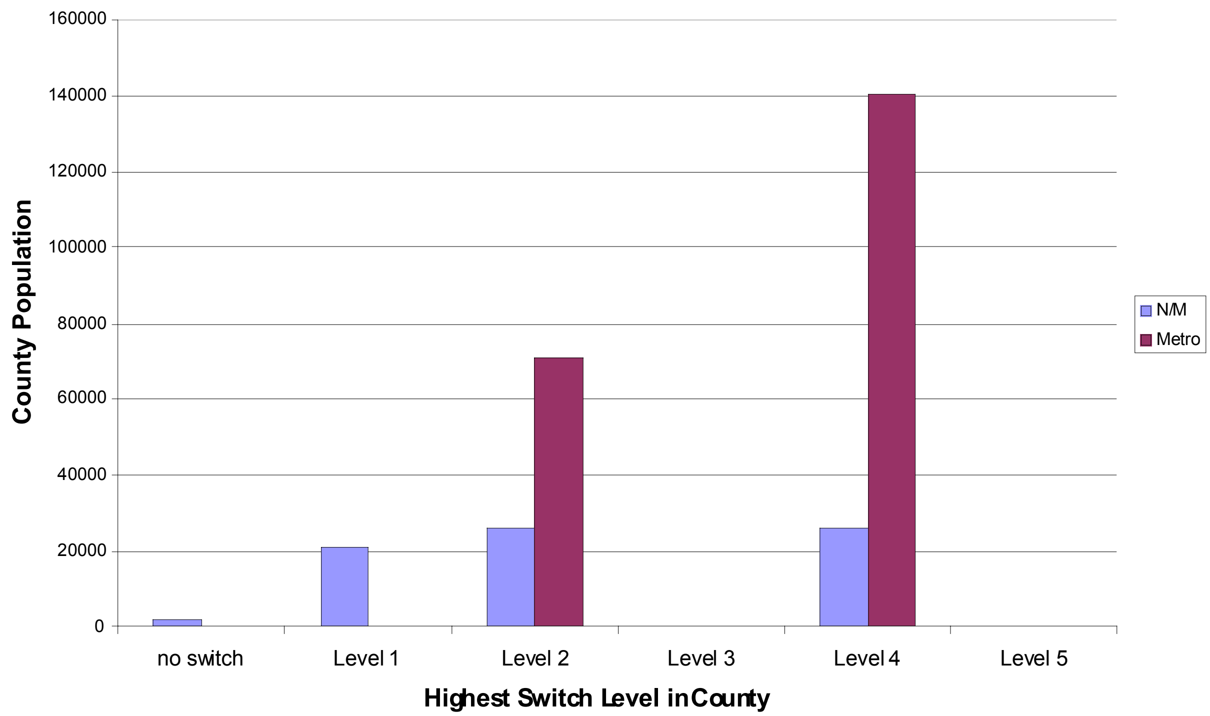


Figure 4. Average Population by Switch Level: MS



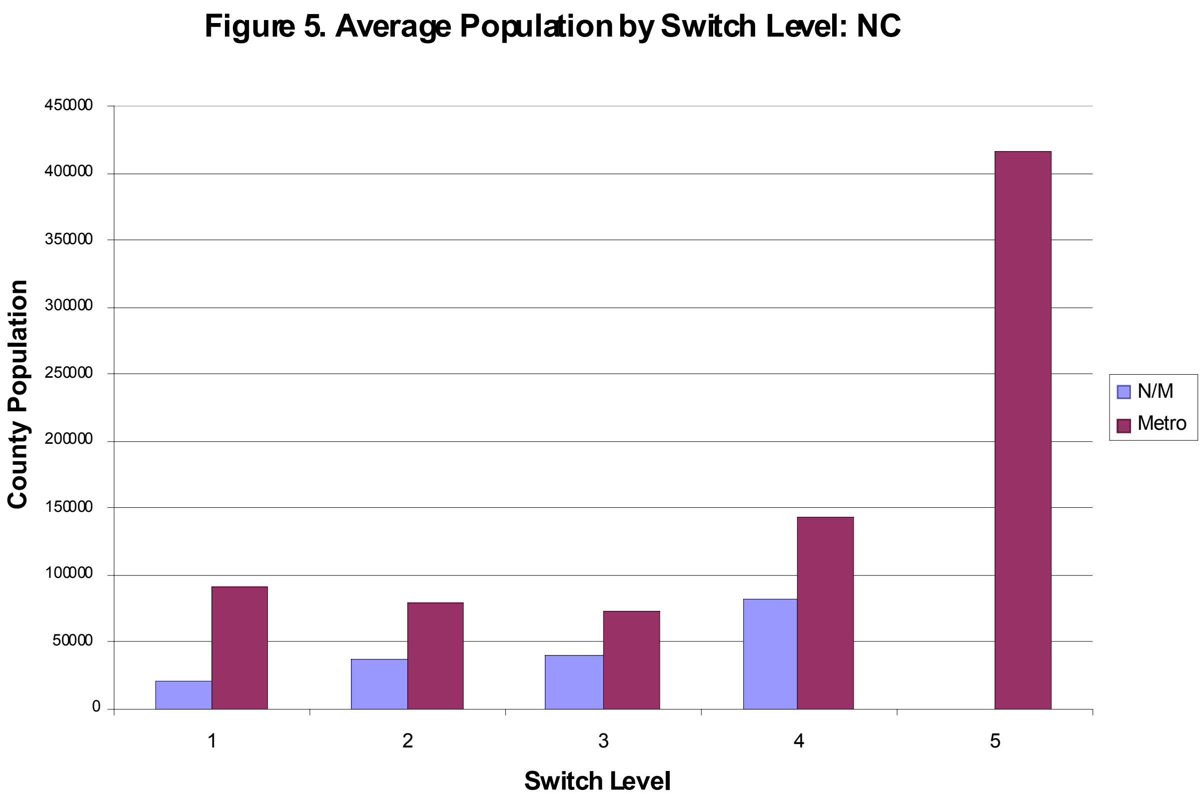
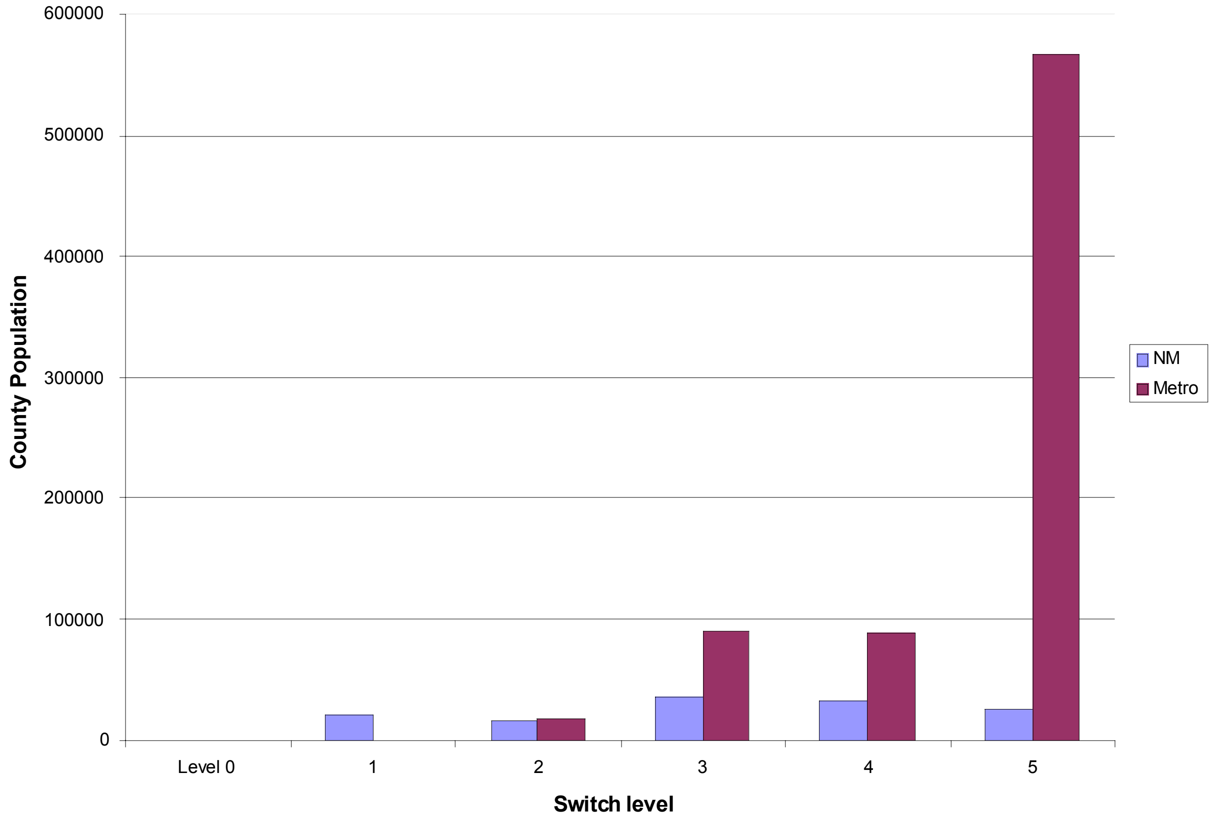


Figure 5. Average Population by Switch Level: NC
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
County Population
1
2
3
4
5
Switch Level
N/M
Metro

Figure 6. Average Population by Switch Level: TN



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