

**TELECOMMUNICATIONS INFRASTRUCTURE AND USAGE  
IN RURAL AREAS:  
A PRODUCTION FUNCTION APPROACH<sup>†</sup>**

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## **ABSTRACT**

This research uses the production function theoretical framework and an extensive, exchange-level database on telephone usage and infrastructure, employment and population, to clarify the relationships between rural economic activities and telecommunications. Relationships are estimated through regression analysis, linking telephone usage, measured in aggregate conversation seconds, by each of eleven economic sectors, to such variables as sectoral employment, rurality of the exchange, availability of advanced telecommunication infrastructure, regional core-periphery location of the exchange, and sectoral growth. The results show that telecommunications and labor are, in most cases, complementary inputs in each sectoral production function, that rural activities use telecommunications less in the absence of advanced technology, but that the latter tend to significantly increase telecommunications usage. This result tends to support the idea that an advanced telecommunication infrastructure in rural areas may be important to attract specific activities, particularly professional services, that make heavy use of telecommunications, and thus to promote rural economic development.

## 1. INTRODUCTION

Telecommunication technologies are claimed to lead to a new urban and regional spatial organization (Graham and Marvin, 1996). In particular, they are believed to promote rural development by attracting information-intensive firms (e.g., producer services) to rural areas, simply because they allow these firms to trade their services beyond their local areas, providing strong multipliers, in contrast to consumer services bound to residential activities. However, the research conducted so far on this subject and consisting primarily of case studies or limited-scope surveys, is not fully conclusive, and suggests that telecommunication advances may be a two-way street for rural areas, because they may also make it easier for urban firms to capture and serve rural markets, thus inhibiting local rural development.

The purpose of this paper is to empirically clarify the relationship between rural economic activities and telecommunications, making use of detailed telecommunications infrastructure and usage data for a region in the northeastern United States, as well as detailed Census data on sectoral employment, all defined at the local exchange (wire center) level. Based on the production function theoretical framework, regression equations are estimated, that relate sectoral telecommunication usage to sectoral employment, telecommunication infrastructure, degree of rurality, and location within the region (e.g., core vs. periphery). The implications of the results in terms of input complementarity and the other effects are assessed.

The remainder of the paper is organized as follows. Section 2 consists in a review of the relevant literature. The conceptual framework is presented in Section 3. The data sources and their processing are described in Section 4. The functional specifications, the empirical results, and their implications are discussed in Section 5. Conclusions are outlined in Section 6.

## 2. LITERATURE REVIEW

Rural studies dealing with the impacts of **Information and Communication Technologies** (ICT) are based on the premise (or speculation) that high-quality ICTs, with their space-transcending capabilities, can help attract footloose industries, particularly information-intensive producer services (PS) firms, the fastest growing component of the U.S. economy, to peripheral and rural areas and contribute to their economic development, simply because ICTs allow these firms to trade their services beyond their local areas. PS activities, whose output is primarily information and knowledge that serve as inputs to producers of goods and services, are considered export (or basic) activities, highly responsive to external demand, and thus with strong impacts on the regional economy. PS firms specialize in Consulting, Computing, Engineering, Finances, Advertising, Insurance, Public Relations, Legal Analysis, etc. In contrast to consumer services, PS firms are not bound to residentiary activities. Kim et al. (1990) analyze the growth of PS in the Seattle SMSA and surrounding rural areas. While they find that PS employment has grown everywhere, they cannot discern a clear decentralization trend towards rural Washington. However, they find that PS opportunities are largest in large rural communities, with high-quality ICTs. They conclude that ICT advances may be a two-way street for rural America: (1) ICTs increase a rural community's access to information and help rural businesses serve non-local markets, but (2) ICTs make it easier for urban firms to capture and serve rural markets, thus inhibiting local rural development. In a related study, Beyers (1994) conducts a survey of PS firms in urban and rural areas of the Pacific Northwest, to analyze their relative competitiveness, the nature of their factor and product market relationships, and how ICTs impact the services they render. Coffey and Polese (1989), studying the growth of PS in Canada from 1971 to 1981, conclude that PS employment growth beyond metro areas

occurs primarily in the form of deconcentration, i.e., extended urbanization, rather than in rural regions and smaller towns, and that the potential for higher-order PS firms to locate outside major metro areas is highly limited. Their view is that ICTs free office functions from locating close to the operations they direct or support, thus contributing to the growing centralization in a small number of large metro areas, a view also supported by Hepworth (1986) and Warf (1989). OhUallachain and Reid (1991), using U.S. data for the period 1976-1986, observe two types of changes in the location patterns of PS firms: (1) a decentralization down the urban hierarchy, where back-office functions are attracted to lower-wage small metro and non-metro areas, and (2) a rapid growth and concentration in several large SMSAs. They hypothesize that this selective decentralization/centralization is associated with inter-firm flows of information, and that minimizing the costs of acquiring information drives firm localization. Hudson and Parker (1990), noting that farming employs only 9% of all rural workers, with half as many in manufacturing, and that, in 1985, the average rural unemployment rate was 18.3% versus 12.7% in urban areas, consider the development of ICTs in rural areas as key to further economic development, leading to improved efficiency in managing rural enterprises and savings in travel costs and times, particularly in areas where the telephone density is the lowest. Egan (1992) discusses the importance of deploying microwave and fiber optics facilities in rural areas, because large services and manufacturing businesses often require broadband communication capability for high-quality data and video transmission to keep up with their urban and suburban counterparts. He also discusses the problems involved in financing such systems, now that the cross-subsidization historically used by rural telephone companies is less and less feasible in the face of competition. Richardson (1994), noting that ICTs facilitate the spatial separation of production and consumption, and allow firms to take advantage of place-specific cost

differentials and to deliver services via the telephone, analyzes the decentralization from London to peripheral regions of firms involved in teleservices, such as travel booking/sales/reservation, and computer direct sales/technical support. Finally, Richardson and Gillespie (1996) analyze the impact of a British government initiative to upgrade ICTs in rural Scotland to attract data-intensive businesses. New jobs, predominantly professional (consultancy, programming) in home-based and small businesses are created, but the vast majority of employment growth is exogenously driven, due to returners with ICT skills. These skills turn out to be difficult to develop within these peripheral regions for export to core markets..

The above review clearly underscores the dearth of systematic empirical studies to identify the relationships between telecommunication infrastructure and use, and rural economic development. Such studies are feasible only with the assembly of the appropriate databases on both the socio-economic structure of rural areas, their relationships to urban/metro areas, and their telecommunication infrastructure. A theoretical framework to analyze and clarify these relationships is presented in Section 3, and its empirical application in Sections 4 and 5.

### 3. CONCEPTUAL FRAMEWORK

Consider a firm that generates  $M$  ( $m=1 \rightarrow m$ ) distinct telecommunication flows of volume  $F_m$ , that make up the vector  $\mathbf{F}$ . These flows combine to generate the information input to the firm,  $I$ , and are constrained by the telecommunication infrastructure available at the firm's location (i.e., exchange). Let  $\mathbf{T} = (T_1, T_2, \dots, T_K)$  be a vector of exogenous variables (e.g., number and type of access lines, switching technology, etc.) characterizing the state of the telecommunications infrastructure. The information production function can be represented by:

$$I = g(\mathbf{F}, \mathbf{T}) \quad (1)$$

The firm's production function relates the output  $Q$  to the information input  $I$ , the labor input  $E$ , and all the other inputs represented by vector  $\mathbf{X}$ , with:

$$Q = f(I, E, \mathbf{X}) \quad (2)$$

Combining Equations (1) and (2) leads to:

$$Q = h(\mathbf{F}, \mathbf{T}, E, \mathbf{X}) \quad (3)$$

Let  $P_Q$ ,  $P_F$ ,  $P_L$ , and  $P_X$  be the prices associated to  $Q$ ,  $\mathbf{F}$ ,  $E$ , and  $\mathbf{X}$ , respectively. The standard problem of the firm is to select the values of the output,  $Q$ , and inputs,  $\mathbf{F}$ ,  $E$ , and  $\mathbf{X}$ , that maximize its profit

$$\Pi = P_Q Q - P_F \mathbf{F} - P_L E - P_X \mathbf{X} \quad (4)$$

subject to the production constraint (3). This optimization leads to the following telecommunications and labor inputs demand functions:

$$\mathbf{F} = \mathbf{R}(\mathbf{T}, P_F, P_L, P_X, P_Q) \quad (5)$$

$$E = L(\mathbf{T}, P_F, P_L, P_X, P_Q) \quad (6)$$

Combining Equations (5) and (6) by eliminating the labor price  $P_L$  leads to:

$$\mathbf{F} = \mathbf{S}(E, \mathbf{T}, P_F, P_X, P_Q) \quad (7)$$

The purpose of the remainder of this paper is to empirically estimate Equation (7).

## 4. DATA

### 4.1 Telecommunications Data

The telecommunication usage data pertain to a 5 percent random sample of all the toll calls that were made within a certain LATA (Local Access and Transport Area) in the northeastern United States during the month of February 1990. This sample was drawn systematically, with a random starting point, from a billing/accounting database. Because of the

proprietary nature of the information, the name of the Local Exchange Company (LEC) that provided the data may not be revealed, and any parameter that might be used to identify it is given on an interval basis only. The LATA is subdivided into [100-200] local exchanges (LEXs), also called wire centers (WCs), each with a central office building housing one or more switches, to which all local loops converge. All calls are intra-LATA exclusively, i.e., originate and terminate within the LATA. (All long-distance inter-LATA calls were handled by carriers such as AT&T and MCI).

The sample is made of [500,000-700,000] calls. Each message is characterized by a large number of variables, including the message date, starting time (hour/minute), duration, and charge; the coordinates of the two wire centers where the message originates and terminates; and the Standard Industrial Classification (SIC) code of the party (caller, callee, or third party) that pays for the message. A complex data processing was undertaken to assign SIC codes to as many calling and called numbers as possible, and is described in more details in Guldman (1993). This SIC-code assignment, which was initially completed for 73.2% of all the calls in the sample, was recently expanded by using SIC identifications available in CD-ROM telephone directories. Toll messages are classified according to their service categories: (1) MTS (Message Toll Service) messages originating at private residential and business stations; (2) MTS-Coin messages originating at coin stations; (3) Out-WATS (Wide-Area Toll Service) messages originating at a WATS number; and (4) In-WATS messages (exclusively 800 calls). MTS-coin messages (3% of all calls) were discarded, because there is no way of identifying the SIC code of coin station users (i.e., we may know that a given station is classified "Retail Trade" because of its location in a shopping mall, but we do not know who is using it). In-WATS 800 calls represent 8% of all calls. Only MTS calls have their charge included in the data base. The

pricing of In-WATS and Out-WATS services involves (1) a fixed monthly access line charge, and (2) a monthly usage charge related to the monthly hourly usage through a declining block rate structure, irrespective of the timing of a call or the location of its destination. Given the rate structure in effect in February 1990, the total monthly usage and the resulting total monthly charge have been estimated for each In-WATS and Out-WATS number in the sample. The resulting average charge ( $\text{\$/second}$ ) has then been used to estimate an equivalent charge for each individual call, based on its duration. Before this computation, all individual call counts, their duration, and their charge, were multiplied by 20 to provide estimates for the total population of calls, based on the 5% sample.

At the completion of the SIC-code assignment process, each telephone number is classified into one of four categories: (1) SIC-identified business (BUSID), (2) SIC-non-identified business (BUSNID), (3) residential (RES), and (4) unknown (MIX). Telephone flows (conversation seconds) have been aggregated by origin exchange along the above categories, and the BUSID flows have been further regrouped into 11 economic sectors, in order to match the available employment data categories:

1. Construction (CON), SIC 15-19,
2. Manufacturing (MAN), SIC 20-39,
3. Transportation, Communications, and Other Public Utilities (TCPU), SIC 40-49,
4. Wholesale Trade (WT), SIC 50-51,
5. Retail Trade (RT), SIC 52-59,
6. Finance, Insurance, and Real Estate (FIRE), SIC 60-69,
7. Business and Repair Services (BRS), SIC 73-76,
8. Personal Services (PERS), SIC 70-72,
9. Professional and Related Services (PROS), SIC 80-89,
10. Public Administration (PA), SIC 90-98,
11. All Other Industries (Agriculture, Mining, Recreational Services) (OTH), SIC 1-14, 78-79.

The origin BUSNID flows were assumed to be distributed across sectors in the same proportions as the origin BUSID flows, and were allocated to the BUSID flows accordingly. The origin MIX flows were assumed to reflect the relative sharing of identified total residential and business flows, and were allocated accordingly. Similar allocations were performed for the destination numbers, but flows were aggregated over all destination exchanges. However, regular business destinations (MTS and Out-WATS) and 800 destinations were kept distinct because their pricing are fundamentally different. The basic flow variables that are finally retained for further analysis are defined as follows:

$MSB_{ki}$  = number of conversation seconds from sector  $k$  located in exchange  $i$  to regular business destinations;

$MSR_{ki}$  = number of conversation seconds from sector  $k$  located in exchange  $i$  to regular residential destinations;

$MS800_{ki}$  = number of conversation seconds from sector  $k$  located in exchange  $i$  to 800 business destinations.

The total flow ( $MST=MSB+MSR+MS800$ ) shares across the 11 economic sectors are presented in the first column of Table 1. Services (Sectors 6-9) make up 40% of the traffic, followed by trade (Sectors 4-5), 30%, and manufacturing, 10%. The distribution of each sector outflow across the three major destinations is also presented in Table 1. For instance, 31.3% of the manufacturing-originated flows go to residential numbers, 59.7% to business numbers, and 9.1% to 800 numbers. The shares of 800 numbers do not vary much across sectors, mostly in the [8%-10%] range. Overall, 66% of the outflow goes to business numbers, and 32% to residential numbers. Using the coordinates of the central office in each exchange, seconds-miles have been computed and aggregated/allocated in the same way as the flows themselves, and average calling distances have been computed. Statistics for total flow calling distances are also presented in Table 1. Overall, calling distance patterns are very similar across the 11 sectors, with MAN and TCPU calling slightly farther than the overall average of 30.3 miles.

Call charges have been aggregated/allocated in the same way as the flows. However, aggregate charges for 800 destinations have not been computed, because, in such calls, it is the 800 number that pays for the charge, and thus this cost is not borne by the caller and has no effect on calling behavior. The following quantities are obtained:

$MCB_{ki}$  = total charge (\$) for all the calls/conversation seconds from sector k located in exchange i to regular business destinations;

$MCR_{ki}$  = total charge (\$) for all the calls/conversation seconds from sector k located in exchange i to regular residential destinations.

Average prices are then derived by dividing total charge by total flow duration:

$$PMSB_{ki} = MCB_{ki} / MSB_{ki} \quad (8)$$

$$PMSR_{ki} = MCR_{ki} / MSR_{ki} \quad (9)$$

Statistics for the average prices are presented in Table 2, and suggest that there are no major differences across sectors and across destinations. As the above average prices are to be used in the econometric estimations, several clarifications are necessary. A major criticism of the average price approach of dividing revenues (i.e., charges), R, by the quantity to be explained, Q, is that it necessarily establishes a negative relationship between Q and the computed price P (=R/Q). This is true for local calling with only a fixed monthly charge, implying a constant price-quantity (P.Q) product, and therefore a price elasticity of -1.0, when, in fact, the observed variations in Q are completely unrelated to the computed P. However, this study does not consider local calling, and focuses on toll calling exclusively. Taylor (1983) has argued for the need to use elements of the rate schedule, in particular the price of the initial period as determinant of the demand for calls, and the price of an overtime period as determinant of the duration of a call. While this is theoretically correct when analyzing the demand of individual customers facing the same rate schedule, in this study the demands for conversation seconds are

aggregations of individual demands under different rate schedules. First, toll users face three basic schedules, depending upon the time of day and day of week. Each schedule is characterized by eight distance intervals, and each such interval is characterized by a fixed price for the first minute, and a variable price applied to each additional minute. For any schedule, all prices increase with distance. Daytime prices are the highest, and evening and nighttime/weekend prices represent about 65% and 35% of the daytime prices, respectively. The normal charge of a toll call, based on length of haul, duration, and timing, may be further adjusted to account for special calling features such as operator assistance, credit card or calling card messages, etc. Second, Out-WATS users face a completely different rate schedule, invariant with time and length of haul. As a result of this calling heterogeneity, there is no specific rate element that can be chosen as a representative price for all calls, and the average price, as computed here, is considered the best overall representation of these different prices. For further support for this approach, see De Fontenay and Lee (1983) and Acton and Vogelsang (1992).

The telecommunications infrastructure data include exchange-level information on the switching technology (digital, analog, electromechanical, step-by-step), and on the different types of access lines (one or multiple party, PBX, Out-WATS and In-WATS, etc.). These data are available for the exchange as a whole, and cannot be assigned to specific groups of users defined by their SIC codes.

#### 4.2. Socio-Economic Data

The LATA has a total area of [25,000-35,000] square kilometers, a 1990 population of [0.8-1.2] million, and [250-350] county subdivisions (city, town, village) spread over [10-15] counties. The urban/rural structure of the population is as follows: 49% rural (hamlets, isolated

farms, and places with less than 2,500); 20% urban, in places with more than 2,500, but outside urbanized areas; and 31% urban in urbanized areas. In 1990, [400,000-600,000] workers (16 years and over) were employed in the LATA, representing an aggregate growth of 43% over the 1980 total employment. Employment data by industry are drawn from the 1980 and 1990 Censuses of Population and Housing, where they are available at the county subdivision level (MCD: Minor Civil Division). The 1980 employment data, drawn from the Census publication Characteristics of Workers by Place of Work, are disaggregated among the 11 sectors described in the previous section. The 1990 employment data, drawn from the Census Transportation Planning Package - State Level, Part B, are slightly more detailed, but have been aggregated to match the 1980 classification. The distributions of employment across the 11 sectors, in the whole LATA in 1980 and 1990, are presented in the first two columns of Table 3. Particularly striking are the strong decline in manufacturing share, and the solid increases in most trade and service sectors.

While some telephone exchanges and MCDs have common boundaries, this is not the general case, and it was therefore necessary to estimate exchange employment (and population) by using the overlay of three GIS maps: (1) the exchange boundary map, (2) the MCD boundary map, and (3) a land-use map for the LATA for the early 1980s. These coverages were overlaid using ArcInfo. The amount of commercial-industrial land was used as the allocation variable to convert MCD-level data to exchange-level data. Of course, any such allocation entails some degree of error, but it is more consistent than using block-level population data, which characterize the residential realm. The latter have been used to allocate population data to exchanges, with a very high degree of precision. The sectoral employment shares have been computed at the exchange level, and their statistics are presented in Table 3. While average

shares are close to the shares for the LATA as a whole, there are significant variations, with some exchanges characterized by a high concentration in specific sectors (e.g., 60.8% in PROS, 57.4% in MAN, 48.8% in RT). Any sector is absent in one or more exchanges. Table 3 also presents statistics on sectoral growth factors, defined as the ratios of the 1990 employment to the 1980 employment. While the average growth factors are all greater than one, thus pointing to overall employment growth, all sectors are characterized by some exchange(s) where employment has been declining, and some exchange(s) where growth has been very strong. Overall, the data in Table 3 point to a regional economy with strong spatial variations in sectoral employment composition in 1990 and in the growth over 1980-1990.

## 5. EMPIRICAL ANALYSES

### 5.1. Model Specification

Equation (7) is adapted to the data described in the previous section. The dependent flow variables are, for each of the 11 economic sectors, the total conversation seconds to the three major destinations: businesses, residents, and 800 numbers. Thus, 33 (3X11) equations are estimated. The labor input is, of course, the total sectoral employment in each exchange, and the telecommunication prices are taken as the average prices described and discussed in Section 4.1. There are no data on the prices of the sectoral outputs and the other inputs (e.g., prices of materials, energy, capital, land, etc.) across the exchanges of the LATA. While some prices (e.g., capital) are unlikely to vary within the LATA, and therefore their effects cannot be captured statistically, other prices may vary, and these variations may possibly be captured by proxy variables, such as the distance between the exchange and the economic core of the LATA, or the urban/rural character of the exchange. Finally, we should allow for possible variations in

the production function across exchanges: for instance, more recently implanted activities may be more efficient than older ones. Let  $\mathbf{L}$  be a vector representing these locational and efficiency variables. The general forms of the three telephone flow functions are then:

$$MSB = f ( E, \mathbf{T}, \mathbf{L}, PMSB ) \quad (10)$$

$$MSR = g ( E, \mathbf{T}, \mathbf{L}, PMSR ) \quad (11)$$

$$MS800 = h ( E, \mathbf{T}, \mathbf{L} ) \quad (12)$$

Two infrastructure variables turned out to have significant effects on the flows:

- ISW =1 if the exchange is equipped with digital switching equipment, =0 if not;
- SWATS = share of WATS (both In and Out) access lines in the exchange.

Close to 60% of the exchanges had digital switching in 1990. The share of WATS lines varies between 0% and 10.3 %, with an average value of 0.9 % (see Table 4).

Two locational variables turned out to have significant effects on the flows:

- RUR = ratio of rural to total population in an exchange;
- DIST = distance (in miles) between the central office and the center of gravity of the LATA, obtained as the barycenter of all the exchanges, weighted by their populations.

RUR varies between 0 and 1, with an average value of 0.84. About 75% of the exchanges have a RUR value above 0.8, and 72% are completely rural. There is only one exchange that is completely urban (RUR=0), and 16% have a RUR value below 0.25. The distance DISP to the regional core varies between 2.4 and 132 miles, with an average value of 42.5 miles (see Table 4). Finally, the sectoral growth factors GRS presented in Table 3 are used as proxies for sectoral dynamism and efficiency. Equation (10) can then be rewritten as:

$$MSB = f ( E, ISW, SWATS, RUR, DIST, GRS, PMSB ) \quad (13)$$

Various functional specifications of Equation (13) have been considered, and a linear-in-logarithms form has been selected, wherein the elasticity of employment is a function of the

variables ISW, SWATS, RUR, DIST, and GRS, with:

$$\ln\text{MSB} = a + b(\text{ISW, SWATS, RUR, DIST, GRS}) * \ln E + c * \ln\text{PMSB} \quad (14)$$

The employment elasticity function  $b(\cdot)$  is specified as follows:

$$b(\cdot) = d + e * \text{RUR} + f * \text{RUR} * \text{ISW} + g * \text{RUR} * \text{SWATS} + h * \text{DIST} + k * \text{GRS} \quad (15)$$

The same specifications were used for Equations (11) and (12), except for the price variable that does not appear in Equation (12).

## 5.2. Results

All regression models have been estimated through OLS. The results are presented in Tables 5-7. Consider first the case of MSB (Table 5). The price elasticities are, except for Sector 11, highly significant (1% level), negative as expected, and in the elastic range. The analysis of the employment elasticities is more complicated. First, consider the case with  $\text{RUR}=0$  (completely urban exchange),  $\text{DIST}=0$  (exchange located at the regional core), and  $\text{GRS}=1$  (no employment change). Because the coefficient of  $\text{GRS} * \ln E$  is small as compared to that of  $\ln E$ , we may focus on the latter as the measure of elasticity, which then varies between 0.403 and 1.018, with most measures in the [0.7-0.9] range. The positive sign points to complementarity between the telecommunication and labor inputs, i.e., the more employees the more conversation seconds. This result casts doubts on the belief, often stated in the literature, that the efficiencies derived from increased use of ICTs allow for a reduction in the labor input needed in production processes. This complementarity is particularly strong in Sectors 9 (0.983: professional services), 6 (0.939: FIRE), and 11 (1.018: agriculture and mining). Elasticities close to one may point to an input-output production function. The lower elasticity for Sector 7 (0.403: business and repair services) is puzzling, but might be due to a predominance of repair services, which may require less telecommunication interactions per employee. Next, consider

how the previous results are modified in a rural environment ( $RUR=1$ ), in the absence of advanced telecommunications infrastructure ( $ISW=0$ ,  $SWATS=0$ ). The coefficients of  $RUR*\ln E$  are all negative, and in most cases significant at least at the 5% level, pointing to an important “rural penalty“, i.e., there is less complementarity between labor and telecommunications in rural areas, and thus less calling per employee. In the cases of Sectors 3 and 7, the elasticities become 0.174 and 0.102, respectively, thus much closer to the pure substitution case (negative elasticity). A relative (e.g., 1%) decline in employment leads to a much smaller relative decline in telecommunication usage, thus implying some degree of substitution. However, the “rural penalty” is reduced by the availability of advanced telecommunication infrastructure, as indicated by the positive signs of the variables  $RUR*ISW*\ln E$  and  $RUR*SWATS*\ln E$ . The impact of having digital switching is significant for only 4 sectors (2, 3, 9, 10), but the impact of having WATS access lines is significant in 9 sectors (1, 2, 4, 6-11). Consider, for instance, Sector 9 (professional services) in a rural exchange. Without these advanced features, the employment elasticity is 0.781 ( $=0.983-0.202$ ). With a digital switch, this elasticity increases to 0.896 ( $0.781+0.115$ ). If 5% of the access lines are WATS lines, it increases further to 1.222 ( $0.896+0.05*6.615$ ). Similar results apply to the other sectors. Clearly, an advanced telecommunications infrastructure leads to a much more intensive use of telecommunications (i.e., telephone flows) in rural areas. Interestingly, when the variables  $ISW$  and  $SWATS$  were introduced into the model separately from the  $RUR$  variable, they turned out to be much less significant, which clearly points to a distinct interaction between a rural environment and advanced telecommunications infrastructure (TI) in generating telecommunications flows. This increased usage may be due to specific subgroups of firms that locate in rural areas to take advantage of the TI, and thus contribute to rural economic development, but the employment

data are not sufficiently disaggregated to test this assumption. The impact of the core-periphery location of an exchange, as measured by the variable  $DIST*\ln E$ , is negative and significant for only five sectors (1, 2, 7, 8, 11), suggesting that the farther away the exchange is located from the regional economic core, the more isolated this exchange is, and therefore the lesser the opportunities for telecommunications interactions. Consider Sector 8 (personal services): distances of 10, 50, and 100 miles would reduce the employment elasticity by 0.03, 0.15, and 0.30, respectively. Finally, the impact of sectoral growth ( $GRS*\ln E$ ) is negative and significant at the 5% level for Sectors 6 and 10, and at the 10% level for Sectors 2 and 4. Consider Sector 6 (FIRE): a growth factor of 2 (doubling of employment from 1980 to 1990) implies a decrease of the employment elasticity by 0.050 (from the benchmark of 0.939). When significant, the effect is small. However, the meaning of the negative sign is unclear (and unexpected). It may be that the nature of the expansion in these sectors (e.g., back-office or production workers) was such that these new activities had lesser needs for telecommunications. To further illustrate the above discussion, the employment elasticities under different locational, growth, and technological configurations are presented in Table 8. The lowest elasticities in all sectors correspond to Case 2, “rural exchange at the core without advanced technology”. These elasticities would be further reduced if the exchange were located at the periphery in the cases of Sectors 1, 2, 4, 8, 9, and 11. The availability of digital switching and WATS lines leads to a strong increase in these elasticities in all sectors. Finally, considering Case 6 (strong employment growth, rural exchange located at the periphery, advanced telecommunications technology), we can see that retail trade and all service sectors (except personal services) have high elasticities (around 1.2), suggesting an intensive use of telecommunications in this environment.

The results in Table 6 for messages to residential destinations are, overall, similar to

those in Table 5 for business destinations. Price elasticities are all very significant, but generally smaller than for business destinations, yet in the elastic range. The effects of a rural environment, of advanced telecommunications infrastructure, and of location with respect to the regional core, are all similar to the case of MSB. Table 9 presents the employment elasticities under the same cases as in Table 8. Again, the lowest elasticities are obtained in Case 2, “rural exchange at the core without advanced technology”. In particular, the elasticity of Sector 7 (business and repair services) becomes negative, indicating pure substitution between labor and telecommunications. The highest elasticities are obtained in Case 4, “rural exchange at the core with advanced technology”, except for Sector 7, the elasticity of which increases to 1.230 with a distance of 100 miles (Case 5).

Finally, the results in Table 7 for messages to 800 numbers destinations turn out to be relatively disappointing, with  $R^2$  varying mostly in the [0.3-0.4] range. The coefficient of  $\ln E$  is highly significant (1%) in all cases, but the results for the other variables are, in most cases, insignificant, except for Sector 7, where the rural, technology, and distance effects are significant and similar to those uncovered in Tables 5-6. Clearly, the behavioral underpinnings of calls to 800 numbers are different from those of the regular ones (paid by callers), and require further research.

In summary, except for the case of 800 calling, the results of this analysis suggest that:

- (1) There is a basic, strong, and complementary relationship between the telecommunications and labor inputs to all the economic sectors in urban areas, with elasticities in the range [0.7-1.1], except for Sector 7 (business and repair services), where they are significantly lower.
- (2) This relationship is uniformly weakened (i.e., less calling per employee) in rural areas, in the absence of advanced telecommunications infrastructure, and in one case becomes one of input

substitution.

(3) The above “rural penalty” is strongly reversed when advanced features, such as digital switching and WATS lines, are available, pointing to a much more intensive use of telecommunications; this effect is specific to rural areas, and was not uncovered in urban areas. This result suggests, but does not prove, that the availability of advanced telecommunications infrastructure in rural areas may serve as an attractor of economic activities that need intensive use of telecommunications. These activities in turn may serve as engines of economic development.

(4) The effect of the distance between the exchange and the economic/population core of the region is negative when significant, except for Sector 7, where it is positive and significant. The negative effect points to a declining use of telecommunications in peripheral exchanges, probably due to lesser opportunities for interactions with the core exchanges. There is no clear explanation for the positive effect for Sector 7.

(5) Whether a sector has been growing or declining (in terms of employment) over the 1980-1990 decade, has, in most cases, no significant effect on telecommunications usage. In the few significant cases (Sectors 4, 6, 10 for MSB; Sectors 4-5 for MSR), the effect is negative, but small. It may be that, in these cases, the employment growth consisted in employees with less need of telecommunications interactions.

(6) The telecommunications price elasticities turn out to be highly significant in all cases, and mostly in the elastic range, a result consistent with earlier research [see the review in Guldman (1998)].

(7) No major differences were uncovered among the patterns of calls to business and residential destinations.

## 6. CONCLUSIONS

Using the production function theoretical framework and an extensive, exchange-level database on telephone usage and infrastructure, employment and population, this paper set out to clarify the relationships between rural economic activities and telecommunications.

Relationships were estimated through regression analysis, linking telephone usage, measured in aggregate conversation seconds, by each of eleven economic sectors, to such variables as sectoral employment, rurality of the exchange, availability of advanced telecommunication technology features, regional core-periphery location of the exchange, and sectoral employment growth. The results show that telecommunications and labor are, in most cases, complementary inputs in each sectoral production function, that rural activities use telecommunications less in the absence of advanced technology, but that the latter tend to significantly increase telecommunications usage. This result tends to support the idea that an advanced telecommunication infrastructure in rural areas may be important to attract specific activities, particularly professional services, to such areas, and thus to promote their economic development.

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Table 1 Telephone Flow Distributions and Calling Distance Statistics

Sector	Total Flow Shares (%)	Flow Distribution Across Destinations (%)			Calling Distance (miles)		
		Residential	Business	800 Numbers	Average	Minimum	Maximum
1	5.6	32.8	57.6	9.6	29.1	7.8	99.0
2	10.4	31.3	59.7	9.1	32.9	9.3	154.3
3	7.1	21.2	74.4	4.4	36.6	6.9	115.5
4	4.6	23.1	67.9	9.0	30.2	5.3	130.1
5	14.3	35.5	53.6	10.9	29.7	7.8	108.5
6	15.9	28.2	64.4	7.4	28.8	6.0	122.6
7	3.2	46.4	45.2	8.3	31.2	6.3	133.3
8	7.9	32.0	59.8	8.2	30.4	9.9	117.9
9	22.9	35.0	58.0	7.0	27.7	2.5	68.3
10	5.4	26.9	64.7	8.5	29.5	9.4	139.7
11	2.3	42.4	51.4	6.2	27.6	5.9	94.8
Total	100.0	31.8	66.1	8.1	30.3	2.5	154.3

Table 2 Telephone Price Statistics (¢/sec.)

Sector	Business Destinations			Residential Destinations		
	Average	Minimum	Maximum	Average	Minimum	Maximum
1	0.53	0.34	2.22	0.52	0.13	6.91
2	0.55	0.29	1.28	0.45	0.15	5.00
3	0.63	0.27	5.95	0.74	0.15	8.45
4	0.58	0.24	1.43	0.48	0.12	5.00
5	0.55	0.29	1.16	0.49	0.16	5.00
6	0.64	0.24	14.86	0.53	0.19	5.83
7	0.55	0.17	2.81	0.53	0.14	7.96
8	0.53	0.32	1.16	0.47	0.14	5.00
9	0.53	0.19	1.21	0.50	0.19	5.00
10	0.55	0.15	1.87	0.87	0.17	34.98
11	0.54	0.24	1.18	0.55	0.11	5.00

Table 3 Sectoral Employment Shares (%) and Growth Statistics

Sector	LATA		Exchanges (1990)			Growth Factor (1990/1980 Employment)		
	1980	1990	Average	Minimum	Maximum	Average	Minimum	Maximum
1	6.2	6.9	11.5	0	30.0	2.32	0.11	12.49
2	30.4	20.6	18.6	0	57.4	1.58	0.25	17.25
3	4.9	5.2	5.4	0	37.9	56.56	0.28	6970.0
4	2.9	3.8	3.1	0	19.7	2.41	0.00	10.66
5	16.7	19.0	16.9	0	48.8	2.36	0.33	35.08
6	5.5	7.1	4.4	0	19.2	2.55	0.39	19.43
7	3.1	4.2	4.4	0	18.4	7.93	0.37	542.0
8	2.8	3.0	4.6	0	57.1	2.39	0.37	36.81
9	20.9	23.5	21.8	0	60.8	1.95	0.66	7.29
10	4.0	3.5	3.2	0	13.4	3.13	0.19	40.39
11	2.5	2.9	6.0	0	33.3	4.44	0.27	252.6

Table 4 General Variable Statistics

Variable	Average	Minimum	Maximum
Rurality Index (RUR) [0-1]	0.84	0	1.00
Distance to Regional Core (DIST) (miles)	42.5	2.4	131.9
Share of WATS Lines (SWATS) [0-1]	0.0092	0	0.1031

Table 5 Regression Models of Conversation Seconds – Case of Business Destinations (MSB)

Variable	Sector										
	1	2	3	4	5	6	7	8	9	10	11
Intercept	6.609 (10.06) ***	6.830 (16.15)** *	8.399 (16.17)** *	7.530 (20.54)** *	5.470 (13.96)** *	6.997 (15.96)** *	7.985 (12.14)** *	7.607 (12.85)** *	6.348 (13.57)** *	7.235 (17.90)** *	6.326 (10.92)** *
lnE	0.884 (9.38)* **	0.720 (13.02)** *	0.623 (6.16)***	0.783 (10.37)** *	0.844 (14.96)** *	0.939 (13.83)** *	0.403 (3.77)***	0.846 (8.43)***	0.983 (17.12)** *	0.723 (9.39)***	1.018 (9.87)***
RUR*lnE	-0.207 (2.74)* **	-0.181 (3.07)***	-0.449 (3.70)***	-0.329 (3.70)***	-0.100 (1.78)*	-0.178 (2.09)**	-0.301 (2.19)**	-0.370 (3.09)**	-0.202 (3.80)***	-0.195 (2.03)**	-0.098 (1.04)
RUR*ISW*lnE	0.049 (0.93)	0.096 (2.14)**	0.165 (1.81)*	0.060 (0.72)	0.063 (1.59)	0.079 (1.26)	0.048 (0.47)	0.129 (1.53)	0.115 (3.28)***	0.128 (1.80)*	0.006 (0.08)
RUR*SWATS*lnE	4.772 (1.85)*	4.084 (1.84)*	3.934 (0.89)	8.286 (2.33)**	2.460 (1.29)	6.960 (2.62)***	15.129 (3.26)***	7.500 (1.93)*	6.515 (3.65)***	9.682 (2.76)***	8.179 (2.46)**
DIST*lnE	-0.0016 (1.91)*	-0.0012 (1.72)*	0.0014 (1.09)	-0.0009 (0.72)	0.0006 (1.12)	0.0007 (0.76)	0.0029 (1.91)*	-0.003 (2.42)**	-0.0003 (0.47)	0.0014 (1.29)	-0.0031 (2.73)***
GRS*lnE	-0.013 (0.96)	-0.034 (1.92)*	-0.00005 (1.09)	-0.030 (1.95)*	-0.004 (0.80)	-0.025 (1.98)**	0.002 (0.60)	-0.005 (0.83)	-0.015 (0.93)	-0.011 (1.99)**	-0.0007 (0.78)
lnPMSR	-2.089 (5.08)* **	-2.805 (7.66)***	-1.756 (4.95)***	-2.134 (5.11)***	2.965 (7.47)***	-1.673 (3.95)***	-1.473 (3.65)***	2.585 (4.69)***	-1.074 (3.53)***	-1.988 (5.39)***	-0.829 (2.15)**
R <sup>2</sup>	0.734	0.846	0.636	0.791	0.864	0.865	0.520	0.715	0.890	0.784	0.660

Significant: at the 1% level \*\*\* ; at the 5% level \*\*; at the 10% level \*

Table 6 Regression Models of Conversation Seconds - Case of Residential Destinations (MSR)

Variable	Sector										
	1	2	3	4	5	6	7	8	9	10	11
Intercept	6.277 (9.73)** *	5.875 (10.93)** *	6.360 (15.42)** *	7.986 (19.11)** *	5.643 (11.06)** *	6.600 (14.07)** *	7.878 (10.90)** *	6.650 (12.32)** *	4.318 (7.30)***	6.145 (10.97)** *	7.537 (12.46)** *
lnE	0.797 (7.85)** *	0.840 (14.69)** *	0.716 (10.09)** *	0.649 (7.63)***	0.873 (15.06)** *	0.819 (8.89)***	0.378 (3.34)***	0.971 (9.13)***	1.152 (16.04)** *	0.841 (8.62)***	0.715 (6.53)***
RUR*lnE	-0.118 (1.41)	-0.199 (3.18)***	-0.124 (1.38)	-0.356 (3.36)***	-0.082 (1.31)	-0.378 (3.51)***	-0.459 (3.30)***	-0.288 (2.26)**	-0.116 (1.79)*	-0.169 (1.40)	-0.314 (3.21)***
RUR*SW*lnE	0.010 (0.17)	0.054 (1.20)	-0.097 (1.38)	0.091 (0.89)	0.017 (0.38)	0.186 (2.25)**	0.135 (1.27)	0.038 (0.43)	0.077 (1.82)*	0.012 (0.13)	0.027 (0.38)
RUR*SWATS*lnE	0.696 (2.01)**	8.630 (3.92)***	10.890 (3.47)	10.090 (2.50)**	5.647 (2.70)***	8.932 (2.65)***	13.498 (2.83)***	8.309 (2.07)**	5.789 (2.75)***	14.956 (3.52)***	11.108 (3.20)***
DIST*lnE	-0.0020 (2.19)**	-0.0028 (3.95)***	-0.0004 (0.37)	-0.0015 (1.04)	-0.0002 (0.37)	-0.0003 (0.29)	0.0050 (2.98)***	-0.0048 (3.45)***	-0.0004 (0.62)	-0.0007 (0.52)	-0.0023 (2.02)**
GRS*lnE	-0.003 (0.21)	-0.014 (1.36)	-0.00004 (1.25)	-0.0297 (1.70)*	-0.0155 (2.97)***	-0.0116 (0.72)	0.0011 (0.29)	-0.0080 (1.21)	-0.0261 (1.33)	-0.0126 (1.57)	-0.0014 (1.53)

Significant: at the 1% level \*\*\*; at the 5% level \*\*; at the 10% level \*

Table 7 Regression Models of Conversation Seconds - 800 Numbers Destinations (MS800)

Variable	Sector										
	1	2	3	4	5	6	7	8	9	10	11
Intercept	-5.619 (1.47)	-2.665 (1.05)	13.990 (4.62)***	-4.847 (2.15)**	-0.397 (0.21)	0.179 (0.09)	-3.186 (0.96)	0.139 (0.05)	-11.687 (3.48)***	-3.648 (1.42)	-12.051 (3.07)
lnE	2.529 (4.02)** *	1.899 (5.20)***	3.080 (5.37)***	2.739 (4.74)***	1.731 (6.25)***	2.163 (5.35)***	1.678 (2.67)***	2.093 (3.54)***	2.921 (6.20)***	2.358 (4.63)***	3.599 (4.70)***
RUR*lnE	-0.873 (1.70)*	-0.210 (0.52)	-0.119 (0.16)	-0.378 (0.53)	0.380 (1.28)	-0.263 (0.51)	-2.725 (3.47)***	-0.787 (1.09)	0.325 (0.75)	-0.927 (1.37)	0.375 (0.53)
RUR*ISW*lnE	0.889 (2.54)**	0.430 (1.42)	-0.156 (0.28)	0.564 (0.85)	-0.066 (0.32)	0.807 (2.11)**	1.167 (1.97)**	0.840 (1.68)*	0.358 (1.24)	1.465 (2.93)***	0.255 (0.51)
RUR*SWATS* lnE	2.250 (0.13)	3.152 (0.21)	43.674 (1.62)*	11.390 (0.40)	1.957 (0.20)	2.444 (0.15)	28.447 (1.04)	-13.719 (0.60)	-8.667 (0.60)	6.846 (0.28)	49.968 (2.01)**
DIST*lnE	0.0056 (1.02)	-0.00005 (0.01)	0.0160 (2.04)**	-0.0017 (0.18)	-0.0038 (1.25)	-0.0009 (0.19)	0.0270 (2.95)***	0.0003 (0.05)	-0.0014 (0.30)	0.0092 (1.25)	-0.0132 (1.66)*
GRS*lnE	0.0130 (0.14)	0.0185 (0.28)	0.0003 (0.99)	-0.0876 (0.72)	0.0126 (0.51)	-0.1601 (2.07)**	0.0227 (0.99)	0.0175 (0.47)	0.1192 (0.89)	-0.0435 (1.13)	0.0065 (0.99)
R <sup>2</sup>	0.294	0.293	0.402	0.321	0.340	0.366	0.320	0.212	0.408	0.353	0.325

Significant: at the 1% level \*\*\*; at the 5% level \*\*; at the 10% level \*

**Table 8 Employment Elasticities for Conversation Seconds to Business Destinations (MSB)**

CASE	Sector										
	1	2	3	4	5	6	7	8	9	10	11
1. RUR=0 DIST=0 GRS=1	0.871	0.686	0.623	0.753	0.840	0.914	0.405	0.841	0.968	0.712	1.017
2. RUR=1 ISW=0 SWATS=0 DIST=0 GRS=1	0.664	0.505	0.174	0.424	0.740	0.736	0.104	0.471	0.766	0.517	0.919
3. RUR=1 ISW=1 SWATS=0 DIST=0 GRS=1	0.713	0.601	0.339	0.484	0.803	0.815	0.152	0.600	0.881	0.645	0.925
4. RUR=1 ISW=1 SWATS=0.05 DIST=0 GRS=1	0.952	0.805	0.536	0.898	0.926	1.163	0.908	0.975	1.207	1.129	1.334
5. RUR=1 ISW=1 SWATS=0.05 DIST=100 GRS=1	0.792	0.685	0.676	0.808	0.986	1.233	1.198	0.675	1.177	1.269	1.024
6. RUR=1											

RUR=Rural population/Total population; ISW=1 if switching is digital, =0 if not;  
 SWATS=share of WATS access lines; DIST=distance (miles) between the exchange central  
 office and the regional core; GRS=Total sectoral employment in 1990/Total sectoral  
 employment in 1980.

**Table 9 Employment Elasticities for Conversation Seconds to Residential Destinations (MSR)**

CASE	Sector										
	1	2	3	4	5	6	7	8	9	10	11
1. RUR=0 DIST=0 GRS=1	0.794	0.826	0.716	0.619	0.857	0.807	0.379	0.963	1.126	0.828	0.714
2. RUR=1 ISW=0 SWATS=0 DIST=0 GRS=1	0.676	0.627	0.592	0.263	0.775	0.429	-0.080	0.675	1.010	0.659	0.400
3. RUR=1 ISW=1 SWATS=0 DIST=0 GRS=1	0.686	0.681	0.495	0.354	0.792	0.615	0.055	0.713	1.087	0.671	0.427
4. RUR=1 ISW=1 SWATS=0.05 DIST=0 GRS=1	0.721	1.112	1.039	0.859	1.075	1.062	0.730	1.128	1.376	1.419	0.982
5. RUR=1 ISW=1 SWATS=0.05 DIST=100 GRS=1	0.521	0.832	0.999	0.709	1.055	1.032	1.230	0.648	1.336	1.349	0.752
6. RUR=1 ISW=1 SWATS=0.05 DIST=100 GRS=2	0.518	0.818	0.999	0.679	1.039	1.020	1.231	0.640	1.310	1.337	0.751

RUR=Rural population/Total population; ISW=1 if switching is digital, =0 if not;  
 SWATS=share of WATS access lines; DIST=distance (miles) between the exchange central  
 office and the regional core; GRS=Total sectoral employment in 1990/Total sectoral  
 employment in 1980.