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## Economies of scope in the U.S. telecommunications industry<sup>1</sup>

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### Abstract

This study examines whether the existence of scope economies leads to reductions in unit costs for a sample of the key firms making up the local exchange sector of the United States telecommunications industry. Data for the years 1988 to 1992 are examined and the results establish that the generation of multiple outputs, using the resources infrastructure that the firms possess, does lead to reduction in average unit costs for the firms studied. The results thus shed light on a hitherto empirically ambiguous issue in telecommunications research, the relationship between diversity of operations and firm-level efficiency. Additionally, the deployment of digital technology has a positive and significant impact in reducing costs, across the multiple cost categories that are analyzed, providing support for the notion that technology diffusion is positively associated with superior firm performance. © 1998 Elsevier Science B.V.

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### 1. Introduction

In the theory of the firm the topic of economies of scope is central, given that a premise of such theory is that firms undertake multiple activities (Penrose, 1995),

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which can then be used to produce multiple outputs (Teece, 1982). The existence of economies of scope remains an important but ambiguous issue in the telecommunications sector as well (Brock, 1994). The evidence in general as well as the evidence for the telecommunications sector is equivocal. Such evidence has been obtained primarily using the trans-log methodology which has been shown to give contradictory results even with the use of exactly the same data-set (Waverman, 1989). Given the convergence that is taking place in the telecommunications sector, the scope economies issue has considerable implications for the evolution of future industry structure (Katz, 1996) calling for fresh empirical investigation.

This article examines whether the existence of economies of scope leads to the enhancement of relative firm-level efficiencies for the local exchange sector of the U.S. telecommunications industry, and the analysis is based on panel data for local operating companies for the five year period from 1988 to 1992. The data are contemporary and the results shed insights on the operational characteristics of a key segment of the U.S. telecommunications industry. For example, if economies of scope are found to exist in the local exchange sector there may well be foregone efficiencies, in terms of the assets that become redundant, if alternate conduits for the provision of content are allowed to be developed. This may then suggest that carriers in this sector can, among other strategies, offer their high-capacity conduits to be used by other content providers for the provision of services which require the use of a customer delivery infrastructure of the type operated by the local exchange companies (Katz, 1996).

The paper unfolds as follows. The next section details conceptual and estimation issues with respect to the issue of economies of scope. Section 3 thereafter contains a description of the design and implementation of the empirical model for the evaluation of economies of scope. To alleviate concerns arising from the use of what is standard but apparently rather flawed methodology in examining economies of scope questions an alternative testing approach is used. Given a panel data-set, a pooled cross-sectional time-series estimation approach is used, while prior economies of scope studies have tended to be primarily either cross-sectional or time-series oriented in nature. Following that section, the empirical results are described. Finally, concluding remarks are given in the last section.

## **2. Issues and analysis**

### *2.1. Issues*

Conceptually, economies of scope arise from two main sources: the spreading of fixed costs over an expanded product mix, and from the cost complementarities that can arise between different output categories if functional activities are carried

out under the umbrella of one firm (Pulley and Humphrey, 1993). Spreading fixed costs contributes to the enjoyment of scope economies when excess capacity, and the associated costs, of indivisible physical resources can be reduced by producing two outputs jointly rather than separately. This is the shared-inputs source of economies of scope which, while allowing firms to expand the number of lines of business that are entered into, permits multi-product firms to enjoy lower relative cost levels (Bailey and Friedlaender, 1982; Panzar and Willig, 1981).

The existence of shared inputs has been recognized as a significant source of efficiencies arising from economies of scope in the early theory of the firm (Clark, 1923). For example, Hicks (Hicks, 1935: 372) had written that “. . . almost every firm does produce a considerable range of different products. It does so largely because there are economies to be got from producing them together, and these economies consist largely in the fact that different products require much the same overhead.”

Cost complementarities arise from the exploitation of firm-specific intangible resources and skills which are transferable among different outputs that are generated by a firm (Bailey and Friedlaender, 1982). If resources are used to develop competencies in certain operational activities, then once these activities have been learnt they can be leveraged to provide other products or services at a considerably-reduced cost per unit. The use of such transferable activities gives rise to economies of scope (Teece, 1980).

Transferable skills which lead to cost complementarities are often based on the exploitation of human-capital based know-how and knowledge (Becker, 1964). What results are firm-specific skills; however, these skills are not necessarily function-specific, but instead can be of a general nature. For example, Clemens (Clemens, 1958: 263) had written that “It is a commonplace of business practice that the production and sales managers work hand in hand to devise new products that can be produced with the company’s idle capacity . . . . What the firm has to sell is not a product, or even a line of products, but rather its capacity to produce.” These capabilities and skills also allow firms flexibility in dealing with uncertainty. When facing demand changes for a product, a multi-product firm can reallocate firm-specific skills among other products with currently greater demand; this then yields higher-value use of the various resources that are involved.

## 2.2. Evidence

In respect of the U.S. telecommunications industry, the evidence is interesting because Evans and Heckman (1984) have found no economies of scope within the long-distance and toll-call operations of the erstwhile combined AT&T organization, thus arguing for the break-up of the toll-call and local exchange components of AT&T’s business. This event took place on 1 January, 1984, with the divestiture by AT&T of its 22 Bell operating companies to 7 regional holding companies. Subsequently, Charnes et al. (1988), using the same data-set as Evans

and Heckman (1984), have found the existence of economies of scope between the local and toll-call operations of AT&T, arguing, therefore, that the break-up of AT&T was a mistake.

With respect to the studies of the telecommunications sector, Waverman (Waverman, 1989: 87) has written that: “The evidence on overall economies of scale . . . would appear to favor the presence of such economies . . . . On the basis of this evidence, one would not, however, rush to the FCC . . . and argue that this econometric evidence supports divestiture between local and toll services but further supports the existence of a single firm in the toll market. The weight of the evidence of all these studies is simply not strong enough, since changing the level of aggregation, the functional form, the constraints imposed, or the objective function dramatically alters the results . . . . Moreover, . . . the evidence cannot adequately disentangle the effects of two factors that both reduce unit costs – economies of scale and technological advance.” Hence, disaggregate analysis, using alternate estimation procedures and relevant controls, is necessary.

### *2.3. Context and data*

The context examined is the local exchange sector of the U.S. telecommunications industry. The data used relate to specific local exchange companies (LECs) for the period 1988 to 1992, obtained from the Statistics of Communications Common Carriers published by the Federal Communications Commission (FCC). Over 1000 companies provide local telephone service in the United States. They range in size from rural cooperatives serving few customers to Bell South Telecommunications Inc. which operates almost 20 million telephone lines. Of these, 54 companies have to file data with the FCC, and have annual revenues of over \$100 million. These firms account for almost 99 percent of the national local telephone infrastructure, and provide the primary land-based backbone for the information superhighway in the United States. Whether the existence of economies of scope benefits each local exchange company in terms of enhancing its operating efficiency is the issue empirically addressed in this paper.

The initial data sample contained information on over 50 firms. Because of some data omission, the final sample consists of 40 of the companies. The FCC data have been often used in the telecommunications literature to examine the cost structure and efficiency of the telecommunications industry. The data contains financial accounting information as well as plant statistics. Prior research (Banker et al., 1996; Crandall, 1991; Majumdar, 1995, 1997; Shin and Ying, 1992) has established that the data are reliable. Additionally, the firms face similar environmental conditions and are, at least for the years that the study has been carried out, local monopolies. Therefore, market structure and industry-level issues are controlled for and data for a reasonably-similar set of firms, undertaking comparable activities and using comparable resources to produce comparable outputs, are examined.

#### 2.4. The economies of scope model

An approach based on estimating a linear multivariate model (Banker and Johnston, 1993) is used to test the role of multiple outputs production in engendering scope economies among the firms. The model has five equations for each of five distinct cost categories, rather than one equation for total costs, and each equation has an identical set of explanatory variables. Scaled separate cost categories are the dependent variables in each of the equations, as follows:

$$\begin{aligned}
 \text{PLANT EXPENSES} = & \beta_{10} - \beta_{11} \text{SCOPE LINES} - \beta_{12} \text{SCOPE CALLS} \\
 & - \beta_{13} \text{SCOPE GEOGRAPHY} \\
 & - \beta_{14} \text{CAPACITY USAGE} \\
 & - \beta_{15} \text{TECHNOLOGY MIX} + e_{1t},
 \end{aligned} \tag{1}$$

$$\begin{aligned}
 \text{NETWORK EXPENSES} = & \beta_{20} - \beta_{21} \text{SCOPE LINES} \\
 & - \beta_{22} \text{SCOPE CALLS} \\
 & - \beta_{23} \text{SCOPE GEOGRAPHY} \\
 & - \beta_{24} \text{CAPACITY USAGE} \\
 & - \beta_{25} \text{TECHNOLOGY MIX} + e_{2t},
 \end{aligned} \tag{2}$$

$$\begin{aligned}
 \text{DEPRECIATION} = & \beta_{30} - \beta_{31} \text{SCOPE LINES} - \beta_{32} \text{SCOPE CALLS} \\
 & - \beta_{33} \text{SCOPE GEOGRAPHY} \\
 & - \beta_{34} \text{CAPACITY USAGE} - \beta_{35} \text{TECHNOLOGY MIX} \\
 & + e_{3t},
 \end{aligned} \tag{3}$$

$$\begin{aligned}
 \text{CUSTOMER EXPENSES} = & \beta_{40} - \beta_{41} \text{SCOPE LINES} \\
 & - \beta_{42} \text{SCOPE CALLS} \\
 & - \beta_{43} \text{SCOPE GEOGRAPHY} \\
 & - \beta_{44} \text{CAPACITY USAGE} \\
 & - \beta_{45} \text{TECHNOLOGY MIX} + e_{4t},
 \end{aligned} \tag{4}$$

$$\begin{aligned}
 \text{CORPORATE EXPENSES} = & \beta_{50} - \beta_{51} \text{SCOPE LINES} \\
 & - \beta_{52} \text{SCOPE CALLS} \\
 & - \beta_{53} \text{SCOPE GEOGRAPHY} \\
 & - \beta_{54} \text{CAPACITY USAGE} \\
 & - \beta_{55} \text{TECHNOLOGY MIX} + e_{5t},
 \end{aligned} \tag{5}$$

where the dependent variables are five separate cost categories discussed sub-

sequently; *SCOPE LINE*, *SCOPE CALLS* and *SCOPE GEOGRAPHY* are the principal independent variables capturing the impact of firms conducting multiple activities; *CAPACITY USAGE* captures the impact of capacity utilization; *TECHNOLOGY MIX* captures the impact of technical change and  $e_{it}$  is a random error term for each equation  $i$  ( $i=1, \dots, 5$ ) for each year  $t$  ( $t=1988, \dots, 1992$ ).

The system of equations is additive and separable with respect to the independent variables. Coefficients are estimated for the entire period from 1988 to 1992 for the sample of firms in the industry as a whole for each equation. Also, the use of pooled cross-sectional time-series panel data affords significant econometric advantages over the use of either cross-sectional separately or just time-series data alone for a single observation (Hsiao, 1986; Schmidt and Sickel, 1984).

### 2.5. Description of telecommunications operations

The nature of telecommunications operations which leads to the specification of the equations in (1) to (5) is described in this subsection. Local exchange companies connect millions of customers to each other. Such connections are given within defined operating territories. A local exchange company organization operates a network-based telecommunications infrastructure. This is the system of total wiring in place, denoting the boundaries and size of each local company. From this system of wires lines go out to connect each customer to every other customer in the local network. Thereafter, by a process of further inter-connections local operating companies are linked to each other in the nation by the long-distance network. Such inter-connections allow national and international communications to take place among a vast number of consumers.

Local operating company customers are of many types: residential, business, and public customers being the common categorizations. Such customers make local or toll calls. Primary resources used by the local operating companies to undertake activities that generate outputs within the network infrastructure are switches, other supporting telecommunications plant and human capital. Switches provide the means of actually energizing the network so that communications can take place. To operate the telecommunications network several types of employees are needed: engineering, maintenance, traffic, plant support operations, customer support services, sales and marketing, billing and accounting, regulatory and legal, human resources management, and general and administrative staff (Green, 1992).

### 2.6. Dependent variables

There are five dependent variables, each capturing the costs associated with the different activities that underlie the provision of telecommunications services. The level of each separate cost category can be influenced by the diversity of outputs within each of the telecommunications companies. For the dependent variables

that are used to capture cost elements in Eqs. (1)–(5), data are based on operating expenses information that are reported in the FCC Statistics of Communications Common Carriers. The cost categories and dependent variables are as follows:

### *2.7. Plant specific expenses (plant expenses)*

The costs of plant specific operations are measured as the sum of network support, general support, central office switching, central office transmission, information origination and termination, and cable and wire facilities expenses that are incurred by the local operating companies. These expenses approximate 28.52 percent of total costs, and are the largest element of total operating costs.

These are costs identifiable with the operation of switching and transmission plant, and reflect the primary direct costs of providing services. The activities undertaken to operate switching and transmission plants can be simultaneously applied to service multiple types of customer lines. The costs incurred are associated with the joint generation of different types of calls, since these calls can be made with the existing network infrastructure in place, leading to reduction in average costs for firms which so exploit the network.

### *2.8. Network and access expenses (network expenses)*

The expenses include network operations, testing, plant operation administration, engineering, and access expenses. They enable the network to be maintained and developed on a continuing basis. These costs are not attributable to a specific plant, and are similar to indirect overhead costs. These costs account for 10.83 percent of the total operating costs. These costs will be incurred irrespective of whether the network produces one or many outputs. To the extent that there are many outputs, then the availability of network maintenance and development capabilities can be utilized in lowering average network and access costs for each firm as a whole.

### *2.9. Depreciation expenses (depreciation)*

This includes telecommunications plant depreciation and amortization expenses. Annual writing-off of capitalized costs account for 26.65 percent of total operating costs on average. Telecommunications is a capital-intensive industry and depreciation-expensing represents the consumption of the physical plant capacity in a given period to generate output. Depreciation expenses are fixed in the short term, given that plant capacity is not easily modifiable, but the existence of plant capacity does permit a company to have the wherewithal to produce lines or calls when necessary. To the extent that such plant capacity can be leveraged to service additional new types of customers or generate a variety of calls depreciation expenses per unit are reduced.

### *2.10. Customer operations expenses (customer expenses)*

The expenses contained in this category include product management, sales, product advertising, call completion services, number services and customer services expenses. These costs are identifiable with enabling the customer to subscribe to the network, generate and complete calls. Customer operations expenses average almost 17.70 percent of total operating costs. Once resources are expended in developing competencies in customer operations activities for one type of customer, or in helping to support more than one type of call, then these activities can be transferred to support other types of customers or calls at a considerably-reduced cost per unit. Such inter-output transfers lead to cost complementarities within local operating companies.

### *2.11. Corporate expenses (corporate expenses)*

Corporate expenses include executive and planning, accounting and finance, external relations, human resources, information management, legal, procurement, research and development, and other general and administrative expenses. These account for 16.30 percent of total operating costs. Again, the activities represented by this expense category lead to cost complementarities in the operations of local exchange carriers, since these activities can be fungible among the many different types of outputs that are generated by the firm.

A scaled statement of data for the average local exchange carrier is given in Table 1. Each cost category, deflated to 1988 using the consumer price index for telephone services obtained from the Statistical Abstract of the United States, published by the Bureau of the Census, is used as a dependent variable for estimation purposes as Eqs. (1)–(5) show. The cost categories have been scaled by total phone calls. Prior studies use number of total access lines to scale variables; however, the number of total phone calls are used in this study. The total phone calls are highly correlated with total access lines, with Pearson and Spearman correlation coefficients 0.980 and 0.986 respectively. The number of total phone calls is a useful measure in reflecting the actual usage of existing resource capacities. While scaling controls for size effects, the scaled and unscaled variables are economically equivalent and the choice between them rests on econometric considerations (Christie, 1987).

### *2.12. Structure of outputs and activities—independent variables*

In the telecommunications industry context, the question arises as to what are the various types of outputs. In a model of a telecommunications network switches provide the impetus behind the transmission of messages through the network, while the actual distribution medium for these messages is the lines. Lines are the primary links from the wired network to individual customers. The outputs are the

Table 1  
Scaled income statement for the average local exchange carrier

1988	1988	1989	1990	1991	1992	All
Panel A: Scaled by total revenues						
<i>Revenues:</i>						
Total revenues	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
<i>Expenses:</i>						
Plant specific	0.1965	0.2019	0.2015	0.2021	0.2070	0.2018
Network and access	0.0762	0.0764	0.0740	0.0752	0.0828	0.0770
Depreciation	0.1945	0.1875	0.1882	0.1842	0.1877	0.1884
Customer operations	0.1189	0.1256	0.1259	0.1298	0.1259	0.1252
Corporate	0.1048	0.1151	0.1156	0.1214	0.1208	0.1156
Total expenses	0.6909	0.7065	0.7053	0.7127	0.7243	0.7079
Net income	0.3091	0.2935	0.2947	0.2873	0.2757	0.2921
Panel B: Scaled by total access lines (Thousand dollars per line)						
<i>Revenues:</i>						
Total revenues	0.7056	0.7072	0.6981	0.6972	0.6987	0.7013
<i>Expenses:</i>						
Plant specific	0.1392	0.1431	0.1410	0.1408	0.1449	0.1418
Network and access	0.0541	0.0540	0.0516	0.0515	0.0575	0.0537
Depreciation	0.1376	0.1320	0.1308	0.1277	0.1301	0.1316
Customer operations	0.0830	0.0875	0.0873	0.0899	0.0857	0.0867
Corporate	0.0732	0.0806	0.0803	0.0839	0.0852	0.0806
Total expenses	0.4871	0.4972	0.4912	0.4938	0.5035	0.4945
Net income	0.2185	0.2100	0.2069	0.2034	0.1952	0.2068
Panel C: Scaled by total phone calls (Dollars per call)						
<i>Revenues:</i>						
Total revenues	0.2301	0.2262	0.2303	0.2302	0.2213	0.2276
<i>Expenses:</i>						
Plant specific	0.0456	0.0460	0.0469	0.0468	0.0460	0.0463
Network and access	0.0173	0.0172	0.0168	0.0168	0.0183	0.0173
Depreciation	0.0449	0.0422	0.0432	0.0421	0.0415	0.0428
Customer operations	0.0267	0.0275	0.0283	0.0292	0.0263	0.0276
Corporate	0.0236	0.0253	0.0262	0.0275	0.0272	0.0259
Total expenses	0.1582	0.1582	0.1614	0.1624	0.1593	0.1599
Net income	0.0719	0.0680	0.0689	0.0678	0.0620	0.0677

local and toll calls made via the use of lines, which can then be considered as inputs which have been energized by the use of switches to connect various customers in the network (Green, 1992). The deployment of lines is not under management control since they have to be supplied on demand to various customers at prices which are regulated for certain customer categories. Lines provided to various types of customers as well as the different types of calls are considered as the outputs which influence scope economies for local operating companies in the present study.

Other than the types of outputs produced with the network infrastructure, the

geographic scope of local exchange companies in the United States vary considerably. A variety of calls can be using a variety of access lines, but these access lines are often provided across a variety of regulatory and geographic jurisdictions. Some of the local exchange companies operate across multiple state boundaries, thus broadening the geographic diversity of the companies concerned.

### *2.13. The impact of capacity utilization*

Network capacity is a key dimension characterizing telecommunications operations. The larger the scale of the network, the more the benefits to customers because of the number of inter-connections available (Antonelli, 1991). The larger the size, the greater the level of sunk costs which, however, have to be borne. Therefore, with more extensive usage of total available capacity the better-off a firm will be. This is so because infrastructure investments are expensive, and need to be recovered rapidly if a process of continuous updating is to be undertaken. In the telecommunications sector, with current fiber-optics technology available, output volume in the future will fill 25 percent of available capacity (Porter, 1987), and under-utilized plant capacity in the industry is prevalent (Schiller and Fregoso, 1991). Thus, capacity utilization assumes importance, and the higher the extent of productive capacity usage the lower the level of operating costs.

### *2.14. The impact of technology mix*

The accurate characterization of technical change, as to plant primitiveness or sophistication, is important as a control factor in empirical work on telecommunications (Waverman, 1989). Technology choice is a key intra-firm decision which has a bearing on industrial competitiveness and the structure of costs within a firm (Clark, 1987). The choice of technology is also an important strategic issue for firms because the quality of technology in the installed-base of a firm is an attractor for customers, because of service quality reasons, who may, therefore, use the system more (Kantrow, 1985). Since technology choice affects firms' activity structures, without consideration of technological advances empirical results in an industry such as telecommunications are likely to be imprecise or biased.

In the telecommunications sector, the basic switching and transmission technology has been analog. Rapid progress has since taken place, characterized by the availability of digital technology and fiber-optic usage in the network. Telephone companies can choose between two different types of switching and transmission network systems to provide services. In general, digital switches and lines are installed in dense urban areas or for business customers since they can be used to serve high density areas efficiently. Analog switches and lines are primarily used in suburban and rural areas for residential users (Egan, 1992). The extent of line digitalization is used to capture technology mix, an approach consistent with prior work (Majumdar, 1997; Shin and Ying, 1992).

Network digitalization is an appropriate way to categorize technical change. It is a relatively new endeavor for firms, though data reporting changes made by the FCC between 1990 and 1991 can bias the estimates. At the current stage of technology evolution, penetration is not high because there is a large installed base of the older technology which in itself is quite modern (Antonelli, 1991). As digitalization proceeds a stronger positive impact on performance is likely to be felt. Nevertheless, digitalization provides firms with faster, more flexible and higher quality of service delivery capabilities. With the use of advanced technologies, companies can increase call usage by offering more value-added services to its customers. Thus, the effect of digitalization is expected to have a positive impact in lowering the level of operating costs.<sup>2</sup>

### 2.15. Measurement of explanatory variables

The variables are *SCOPE LINES*, *SCOPE CALLS* and *SCOPE GEOGRAPHY*, capturing scope economies; *CAPACITY USAGE* capturing capacity utilization; and *TECHNOLOGY MIX* capturing the impact of technical change.

### 2.16. Scope lines

This is the access line diversity index, calculated as the inverse of the Herfindahl index (HI) of a carrier's access line mix. A local operating company's access line mix consists of (i) single business access lines [SB], (ii) multiple business access lines [MB], (iii) public access lines [PU], (iv) residential access lines [RE], (v) mobile access lines (MO) and [vi] special access lines [SP]. The *SCOPE LINES* variable can be represented as:

$$SCOPE LINES = 1/HIL, \quad (6)$$

where *HIL* is the Herfindahl index of a carrier's access lines, calculated as  $[(SB/LINE)^2 + (MB/LINE)^2 + (PU/LINE)^2 + (RE/LINE)^2 + (MO/LINE)^2 + (SP/LINE)^2]$ <sup>1</sup>, and where *LINE* is calculated as  $SB + MB + PU + RE + MO + SP$ .

The Herfindahl index has been widely used as a measure of concentration or dispersion of business activities (Shepherd, 1986). It is a useful tool to measure diversity or the concentration of activities at the level of the firm. After taking the inverse of the index, the higher the resultant variable, the greater the degree of

<sup>2</sup> In the telecommunications industry a factor that influences the operating efficiency of local exchange carriers is the urban versus rural composition of the operating territory. Large metropolitan areas permit the optimal usage of physical apparatus (Green, 1992); on the other hand, such areas absorb a larger proportion of other organizational resources. Prior research (Majumdar, 1995) which has investigated efficiency issues for this sector of the industry did investigate the effect of urbanization on local exchange carriers' efficiency but found that the urbanization variable had no significant effect on efficiency.

access line diversity. A higher dispersion of lines suggests the existence of scope economies and associated lower levels of operating costs, which imply that greater operating cost efficiencies are being enjoyed by the firms. If, on the other hand, the coefficients of *SCOPE LINES* are significant and positive, the existence of scope diseconomies are confirmed.

### 2.17. Scope calls

This variable is specified as the proportion of call usage constituted by toll calls. Local exchange companies primarily produce local calls [LC], but all of them also produce toll calls [TC] to varying degrees. Toll calls are long-haul calls which, while needing some different infrastructure like trunk switches, can also utilize the skills acquired in undertaking local call activities. Local operating companies primarily generate intra-LATA toll calls which take place within the boundaries of a state, as opposed to toll calls which are national or international in character. Thus, it is likely that the level of ease or difficulty in managing long-haul versus short-haul activities for these firms are similar. Also, what local telecommunications firms really provide is the capacity to make calls with their given sets of resources. Hence, with greater toll usage there is likely to be leverage of resources which leads to lower operating costs. The computation of the variable is carried out as for the *SCOPE LINES* variable. Thus,

$$SCOPE CALLS = 1/HIC, \quad (7)$$

where *HIC* is the Herfindahl index of a carrier's calls, calculated as  $[(LC/CALLS)^2 + (TC/CALLS)^2]$  and where *CALLS* is calculated as  $LC + TC$ .

### 2.18. Scope geography

Local exchange companies exhibit diversity with respect to the geographic scope of their activities. There are a number of single-state operators such as Pacific Bell (a part of Pacific Telesis) or New York Telephone (a part of NYNEX). Conversely, there are a number of multi-state operating companies such as New England Telephone (a part of NYNEX) or GTE North. For multiple-state operators the experience of operating within one state can be leveraged towards the operations conducted in another state since the demographics and regulatory environments between states may be similar but provide organizational variety. Variety in such local knowledge and the exploitation of geographic spillovers (Jaffe et al., 1993) can be channelized to improve operations for the local operating entity as a whole. The measure used to capture the presence of geographic and regulatory variety is a dummy variable coded as 1 if the local exchange operator is a multi-state entity and 0 otherwise, in other words a single-state entity.

### 2.19. Capacity usage

This variable proxies for capacity utilization. It is measured as the ratio of the total phone calls to total switches. The larger the measure, the greater is the capacity utilization with cost efficiencies arising from firms' abilities to utilize capacity. If the coefficients of the variable are significant and negative, the hypothesis of higher cost efficiencies associated with higher capacity utilization is supported. In the telecommunications industry capacity is available from two sources. First, the wires permit greater connections through a larger number of access lines; therefore, greater customer usage of the system takes place. Second, switches have a certain capacity which permits customer usage of the subsequent wires. However, switches and number of lines are highly correlated and only one source of capacity can be used to derive the variable. In the interests of superior performance, firms are expected to try to attain as much capacity utilization as possible. Therefore, negative signs for *CAPACITY USAGE* are expected to be observed in each of the equations.

### 2.20. Technology mix

This variable measures the quality of technology in the installed-base of the local operating companies. The digitalization process is assumed to occur evenly throughout the year. The measure for quality of technology, *TECHNOLOGY MIX*, is determined as the average percentage of access lines that are digital access lines, and *TECHNOLOGY MIX* in year  $t = (\text{percentage of digital access lines in year } t - 1 + \text{percentage of digital access lines in year } t) / 2$ . The larger this measure, the higher is the level of sophistication of the technological quality of the installed base. The coefficient estimates of *TECHNOLOGY MIX* are hypothesized to be negative for all cost categories.

### 2.21. Estimation procedures

The five equations are estimated separately as well as using the seemingly unrelated regressions estimation [SURE] procedure (Zellner, 1962), based on the pooled cross-sectional time-series data described earlier. The data are examined for multi-collinearity, and the residuals are examined for evidence of violations of ordinary least squares (OLS) assumptions such as heteroscedasticity, serial and contemporaneous correlations. If collinearity is present, OLS estimators of the standard errors of the coefficient estimates are large though coefficient estimates are still unbiased. As a result, the power of hypotheses testing are low (Judge et al., 1985). Since most of the variables are scaled by total phone calls, collinearity is not expected to be a problem. Though explanatory variables have trended data, coefficient estimates and the corresponding variances are stable with respect to small perturbations in the data set. The condition indices and proportions of

variation in the eigenvector-based diagnostics, as set out in Belsley et al. (1980), are less than 20 and 0.5 respectively, well within acceptable limits.

With unscaled variables heteroscedasticity may be expected because observations for firms operating at larger scales are likely to have larger variances than those of smaller carriers, or vice versa. However, scaled variables are used and the results of the Glejser (1969) and Goldfeld and Quandt (1972) test procedures for heteroscedasticity provide no evidence for the existence of heteroscedasticity. Therefore, no adjustments are required to be made.

With time-series data serial correlation is likely. In the presence of serial correlation, the OLS estimation of a system of equations will produce inconsistent parameter estimates. In particular, an OLS procedure that fails to take account of the unobserved error-term differences is likely to overestimate the coefficients on variables since the variable factors are positively correlated with the unobserved error term. Serial correlation is expected in the data since the observations are yearly and the effects of random shocks are likely to last longer than one year. This is due to a general tendency for firms to continue operating as in previous years, and consequently take more than one year to adjust to changes in the environment. Evidence of serial correlation is found among residuals, with estimates of the autocorrelation coefficients ranging from 0.513 for corporate expenses to 0.695 for customer operations expenses. To compensate for the effects of serial correlation, the first-order autocorrelation coefficients are estimated using a variant of the Prais and Winsten (1954) estimator proposed by Park and Mitchell (1980). The data are transformed, including the first observations for each time series, in the usual manner, and a second set of regressions are estimated.

The Park and Mitchell (1980) version of the Prais and Winsten (1954) estimator is consistent, performs well for a small number of periods and trended data, in relation to several other estimators, and reduces the extent to which the autocorrelation coefficient tends to be underestimated. It also yields smaller root-mean-square errors for both the autocorrelation coefficient and the regression estimates in most cases (Park and Mitchell, 1980; Kmenta and Gilbert, 1970). Using all-period observations, the estimator provides more efficient estimates of the autocorrelation coefficients than estimators that do not transform the first observation (Park and Mitchell, 1980; Doran and Griffiths, 1983).

If an overall question requires the estimation of two or more regression equations it is likely that the disturbance terms between these two equations are correlated, since there can be commonalities between firms' operating functions as captured by the various separate regression equations. Such contemporaneous correlation, between the disturbances for each of the equations that we estimate, can have an impact on the efficiency of the estimates generated. If contemporaneous correlation is present, the coefficient estimates of separate regressions do turn out to be unbiased and consistent but are inefficient and the estimates of their variances can be biased (Park, 1967). If so, the technique of multivariate regression generally gives more efficient estimates than the regressions applied

separately to each equation. Further, if two or more equations share the same parameters, as the equations in this study do, then these equations must also be estimated jointly to impose cross-equation constraints (Davidson and MacKinnon, 1993).

Additionally, with respect to correcting for contemporaneous correlation, Doran and Griffiths (1983) find that further losses in efficiency take place when the data are trended, and when there is greater inter-firm correlation among the explanatory variables across equations. Estimating the model as a set of seemingly unrelated regressions helps to correct for contemporaneous correlation and the procedure is used for the present analysis. Such estimation results in only minor changes in the coefficient estimates for the explanatory variables and decreases in some of the estimates of standard errors. Finally, to help ensure that the inferences are reasonable, the criterion proposed by Belsley et al. (1980) is employed to remove influential observations and then reestimate the models. After omitting the outliers, the results remain unchanged.

### 3. Results

The results of the regressions are presented in Table 2. As shown, the percentages of the variations in operating costs explained by the variables range from 8.3 percent to 17.2 percent in the 5 different equations. The  $F$ -statistics are all statistically significant.

The estimates in Table 2 generally turn out as hypothesized. The explanatory

Table 2  
Regression results. (Coefficient estimates with absolute  $t$ -statistics in parentheses)

Variable	<i>PLANT EXPENSES</i>	<i>NETWORK EXPENSES</i>	<i>DEPRECIATION</i>	<i>CUSTOMER EXPENSES</i>	<i>CORPORATE EXPENSES</i>
<i>Intercept</i>	2.26E-2*** (8.347)	6.89E-3*** (4.481)	2.68E-2*** (7.992)	1.44E-2*** (6.932)	9.82E-3*** (6.596)
<i>SCOPE</i>	-1.28E-2*** (3.618)	-1.96E-3 (1.267)	-1.13E-2*** (3.255)	-3.38E-3* (1.407)	-1.68E-3 (0.885)
<i>SCOPE</i>	-4.63E-3 (0.885)	1.96E-3 (0.873)	-4.96E-3 (0.986)	-6.62E-3** (1.879)	-2.05E-3 (0.734)
<i>CALLS</i>	-1.23E-3 (0.698)	-5.37E-4 (0.701)	1.81E-4 (0.106)	-1.62E-3* (1.354)	-7.94E-4 (0.837)
<i>SCOPE</i>	-1.86E-7*** (3.034)	-7.71E-8*** (2.899)	-1.73E-7*** (2.927)	-7.45E-8** (1.782)	-1.13E-7*** (3.378)
<i>USAGE</i>	-3.55E-5 (0.667)	-5.26E-5** (2.228)	-9.70E-5** (1.900)	-5.97E-5* (1.643)	-6.05E-5** (2.075)
<i>TECHNOLOGY</i>	0.172	0.111	0.173	0.083	0.108
$F$ -Statistic	8.089	4.829	8.133	3.504	4.684
$p > F$	0.0001	0.0003	0.0001	0.0047	0.0005

All tests one-tailed except the intercept term; \*\*\*  $p < 0.01$ ; \*\*  $p < 0.05$ ; \*  $p < 0.10$ .

variables *SCOPE LINES*, *SCOPE CALLS* and *SCOPE GEOGRAPHY* capture scope economies and their coefficient estimates are as follow: *SCOPE LINES* is negative for all of the 5 equations, and significant in all but the *NETWORK EXPENSES* and *CORPORATE EXPENSES* equations, which suggests that the greater the diversity of access lines provided the lower the average units costs are for the local exchange companies. *SCOPE CALLS* is negative in all but one of the equations and significant in the *CUSTOMER EXPENSES* equation, while *SCOPE GEOGRAPHY* is also negative in all but one of the equations and significant for the *CUSTOMER EXPENSES* equation.

The signs on the estimated coefficients for access line diversity, *SCOPE LINES*, suggests that with diversified access services provided to different customer groups in a given network, activities become fungible and costs levels can be reduced. Thus, by adding a variety of access lines to its network, a carrier can utilize its production capacity efficiently and obtain scope economies. With access line diversity, carriers can tap a greater variety of customers with different price elasticities. Such customers can often be used to cross-subsidize others, depending on the price elasticity of demand of various groups of users who interact with the network.

The variable *SCOPE CALLS* is not always significant, though always negative as predicted, and possibly technological complexity of the exchange may be vitiating against the full enjoyment of positive benefits that arise from activity sharing. Toll calls require different types of equipment such as trunk switches; consequently, the scope economy impact on costs can be vitiating since additional plant-specific capabilities have to be created within the firm. These capabilities may not always be easily leveraged across the rest of the firm. *SCOPE GEOGRAPHY* is also not always significant, though always negative as predicted, and state-specific skills may not always be usable or transferable within the totality of a multi-state local exchange's company's operations. The overall results are also consistent with similar findings established using simulation methodology by Gabel and Kennet (1994).

The coefficient estimates for *CAPACITY USAGE*, which captures the impact of capacity utilization, are all negative and their corresponding *t* statistics are significant at conventional levels in all the 5 equations. This indicates that average operating costs are lowered with higher capacity utilization, supporting expectations. This evidence is also consistent with previous telecommunications cost studies (Waverman, 1989), and sheds light on the importance of fully utilizing the fixed infrastructure in place to recover all associated costs. Local telephone companies are localized monopolies primarily because it is wasteful to duplicate assets. With modern technology available, the capacity of message transmission has gone up. Those companies that encourage usage of their infrastructure tend to have lower unit operating costs.

Management of tasks related to switching activities can be difficult, since switches vary in size, technology and applications. Hence, capacity utilization with

regard to switches is somewhat difficult because switches are less commodity-like compared to, say, wires. Nevertheless, it is seen that capacity utilization of switches is strongly related to all categories of costs. With better switching capacity management, telecommunication plant and network operations become cheaper. Similarly, with higher switch capacity utilization rates, average levels of depreciation, customer operations and corporate expenses for the firms studied are lowered.

It may be recalled that *TECHNOLOGY MIX*, which is the variable capturing the impact of technical change on performance, was expected to be negatively related to all cost categories. As shown in Table 2, the variable has negative and significant coefficients for all but one of the operating cost categories. Thus, lower operating costs, on average, are incurred if firms change-over to new technology, and this is an important empirical finding for the literature dealing with the consequences of technical change at the level of the firm. This finding is also consistent with other recent evidence for the U.S. telecommunications industry (Majumdar, 1997). Digitalization aids local operating companies in becoming scale efficient because time-division based technology permits greater flexibility in the use of telephone networks' resources. Further cost savings from the deployment of advanced technology can, however, be expected as digital technology diffuses over time in the U.S. local exchange networks.

#### 4. Concluding remarks

This study demonstrates the impact that scope economies have on local exchange carriers' operating costs. Understanding whether there are, or there are not, significant economic gains to being a multi-product firm is important, since the issue of what the economic consequences of diversification are on firms is an important topic in telecommunications research (Brock, 1994). Theoretically, firms are considered a collection of multiple resources and capabilities which can enhance economic performance if these capabilities are properly utilized (Penrose, 1995; Teece, 1982). Resource commitment choices made by firms influence how diverse their product offerings are. Given greater diversity, the capabilities pool can be leveraged across multiple activities, lowering average costs.

Identification of scope economies and sources of operating efficiencies is helpful for managers. Knowing how resource-deployment strategies impact on costs gives managers insights into where their attention ought to be focused. For the firms studied, the models estimated suggest that local exchange carriers striving to reduce their operating costs have several options. The data show that creating greater access line diversity, by supplying access lines to more customer categories, has a relatively stronger impact on costs, as compared to using these access lines to produce diverse outputs. There are, nevertheless, economic benefits to generating multiple outputs as well. Thus, firms which can simultaneously

provide diverse customer access lines, and then motivate these customers to generate a greater variety of calls will have the most to gain. Geographic diversity does help too, but not yet significantly. Hence, expanding geographic diversity further, a strategy that will be feasible in the newly opened up telecommunications environment, will have positive outcomes on the economic performance of the firms.

From a policy stand-point the existence of scope economies engendering operating cost efficiencies at the local exchange level is an important finding. Local exchange companies are key players at the forefront of the emerging competitive telecommunications environment. Hitherto, they have been monopolists controlling final access to customers. The data, however, show that these companies do gain in economic terms if their infrastructures are leveraged to provide services to multiple categories of customers. Thus, local exchange companies can diversify their activities without negative economic consequences. The utilization of a common pool of resources to provide service-benefits to multiple constituencies is an issue for serious consideration. Using the local exchange infrastructure to provide value-added as well as cable services can lead to potential cost-reductions for the company as a whole. Whether such efficiency motivated diversification efforts then lead firms to subsequently enhance their market shares is also a germane research issue.

Management of the switching network through better utilization also yields savings. Hence, enhancing capacity utilization, say by innovative pricing, ought to be a key strategic thrust for the companies concerned. Digitalization lowers operating costs as well, though average diffusion is low; hence, with greater diffusion of digital technology in subsequent years, the increasing level of sophisticated technology will have further impact in lowering operating costs. This implies that there are economic benefits to the firms studied in being proactive new technology adopters. The continuing adoption of digital technology is a crucial strategic decision for firms to make, since the technology cannot only change the way operational processes are conducted within firms but also enhances competitiveness by giving the acquiring firms a source of advantage over other firms which is manifested as a higher level of operating efficiency.

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