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Demand and pricing of telecommunications services: evidence and welfare implications

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Although telephone pricing has received increasing attention in recent years, the geographic patterns of telephone pricing and the corresponding economic consequences of those patterns have remained perplexing to consumers and policymakers and largely unaddressed by economists. In this article we first specify a model of the demand for short (intraLATA) long distance calling. We then draw upon data made available by the recent adoption of extended area service (EAS) in four metropolitan areas to empirically measure the structure of interexchange telephone demand. Given these estimates, and a conceptual framework for analyzing the economic welfare effects, we are able to quantify the consumer-surplus effects of alternative pricing policies. The empirical results indicate that consumer surplus is noticeably enhanced by adopting EAS. But the net economic welfare effects are shown to be sensitive to, among other things, the level of price-cost margins prevailing prior to the implementation of EAS.

1. Introduction

■ Telephone pricing has both intrigued and befuddled economists and policymakers for over a century. Indeed, substantive issues involving both positive and normative questions about telecommunications pricing have proved to be remarkably enduring. Normative economic analysis of telecommunications pricing has led to the development of principles of optimal (quasi-optimal) linear and nonlinear pricing of telephone services. Positive economic analysis of telephone pricing has recognized the role of both federal and state regulatory bodies in establishing telephone pricing levels and patterns. Because regulators are often subject to intense political (interest-group) pressures, regulatory outcomes often more closely reflect the strength of opposing interest groups than the optimal results derived from normative analysis.

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Against this backdrop, a number of recent articles have extended our knowledge of a variety of aspects of telephone service pricing.[1] Yet despite this progress, the geographic patterns of telephone pricing and their corresponding economic consequences remain perplexing. Specifically, for a typical residential customer of telephone services in the United States, calling within the local calling area (LCA) entails a marginal price of zero, with the exception of the opportunity cost of additional time spent on the phone.[2] For calls outside the LCA, however, prices typically reflect call duration, distance of the call, and time of day. Moreover, it is widely acknowledged that the price of these toll services is generally set well in excess of their economically efficient levels.[3] Thus, calls within LCAs create economic distortions because their price (zero) is less than the positive marginal cost of making them.[4] Simultaneously, the price of inter-LCA calls creates an opposing (but possibly larger) economic distortion due to prices that are set above economically efficient levels.[5] Finally, the differences in these price structures occur despite the fact that a very large portion of "local" (i.e., intra-LCA) calling is technologically indistinguishable from "long distance" (i.e., inter-LCA) calling. (See Kahn and Shew (1987).)

The sizes and boundaries of LCAs are quite diverse. For instance, in the United States, the size of LCAs varies from just a few square miles to massive, the latter exemplified by the large LCAs surrounding such cities as Denver, Atlanta, and Birmingham. Indeed, the roughly 2,400 square miles of the Denver local calling area is considerably larger than the entire state of Delaware. Moreover, the particular boundaries of LCAs are often confusing to customers. For example, it is difficult to understand why calls made between Alexandria, Virginia and Great Falls, Virginia (about 25 miles apart) are local calls, while calls between Great Falls and Leesburg, Virginia (about 10 miles apart) are priced as toll calls.[6]

In recent years, LCAs have been expanded in a number of states.[7] These expansions are generally referred to as extended area service (EAS). In this article, we specify a model of the demand for short (intraLATA) long distance calling. We then draw upon data made available by the recent adoption of EAS in four metropolitan areas to empirically measure the structure of interexchange telephone demand. Given these estimates and a conceptual framework for analyzing the economic welfare effects, we are able to quantify the effects of alternative pricing policies.

The article proceeds as follows. Section 2 provides a background discussion of the structure and implementation of extended area service in the four major metropolitan areas

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[1] See, *inter alia,* Mitchell (1978), Griffin (1982), Park, Wetzel, and Mitchell (1983), Kahn (1984), Kahn and Shew (1987), Griffin and Mayor (1987), Train, McFadden, and Ben-Akiva (1987), and Kaserman, Mayo, and Flynn (1990). For a recent review of the telecommunications pricing literature, see Mitchell and Vogelsang (1991).

[2] Nearly 75% of residential subscribers and almost 50% of business subscribers pay a flat monthly charge and no additional price to call subscribers within the LCA. See NARUC (1989).

[3] Kahn (1984) clearly describes the existence and sources of such inefficiencies. In recent years the magnitude of these inefficiencies has fallen as regulators have reduced (though not eliminated) the degree of long distance-to-local cross-subsidization. For a discussion of the evolution of this pricing phenomenon, as well as an empirical model of its determinants, see Kaserman, Mayo, and Flynn (1990).

[4] We abstract from the network externality here. While the theoretical existence of this externality is incontrovertible, in all likelihood its size is quite small. See Perl (1983).

[5] See Griffin (1982) for an empirical study of these distortions.

[6] Historically the boundaries of LCAs have been justified according to a "community of interest" standard. While there is no single such standard that prevails across all jurisdictions, the most frequently cited indicators of "community of interest" are the absolute and relative intensity of calling volumes between the relevant exchanges. Given the vagueness in these criteria, an interesting question of political economy arises regarding whether such boundaries are determined by interest group pressures suggested by the economic theory of regulation. For a more detailed discussion of this issue, see Martins-Filho (1992).

[7] Proposals to expand LCAs may be initiated by citizens, local exchange companies, or state public utility commissions. They must ultimately be approved by state public utility commissions if the LCA is within a state and by the Federal Communications Commission if it crosses state lines.

in Tennessee. We specify a demand model for telecommunications services to and from these metropolitan areas in Section 3. In Section 4 we present the results of the demand models, which provide the foundation for the welfare estimation. The welfare framework and consumer-surplus impacts associated with EAS are then presented in Section 5. Section 6 contains a discussion of caveats and extensions, and Section 7 concludes.

2. Background

■ In 1990, the Tennessee Public Service Commission ordered South Central Bell to implement an extended area service calling plan for the four major metropolitan areas in Tennessee (Memphis, Nashville, Knoxville, and Chattanooga). The change in the pricing structure associated with the EAS plan, together with data on calling patterns before and after the implementation of EAS, provides a unique opportunity to determine the responsiveness of telecommunications demand to price changes. Moreover, as we see in Section 5, these estimations also permit an evaluation of the consumer-surplus consequences of alternative pricing policies. In the present section, we describe the EAS plan and the demand model employed.

As seen in Table 1, the exchanges affected by the plan were divided into two groups, namely, *CORE* and *NEW*. The *CORE* group corresponds to exchanges that were part of the same local calling area before EAS. The *NEW* group corresponds to exchanges that were added to *CORE* to form the larger calling area that emerges with EAS. The number of telephone calls between each *CORE* (*NEW*) and *NEW* (*CORE*) exchange were recorded for each metropolitan area during the three months before and after EAS implementation. We therefore have the following representative observation: $CALL_{(x,z),t}$, where (x, z) is an ordered pair (therefore, $(x, z) \neq (z, x)$) representing calls from x to z; $x \in CORE(x \in NEW)$ and $z \in NEW(z \in CORE)$ in time period t, where $t = 1$ and 2 for the three months before and after EAS introduction, respectively.[8] For convenience, let each pair (x, z) be indexed by i, thus calls from x to z in time t will be denoted by $CALLS_{it}$.

The EAS plan was implemented at different dates for the four metropolitan areas. Because the collection of the post-EAS data was done during the three months immediately following EAS introduction, the collection period for each metropolitan area is different. For Chattanooga and Memphis, the post-EAS data are for July, August, and September 1990; for Knoxville, the data cover the period from mid-July to mid-October; and for Nashville, the data cover August, September, and October. The pre-EAS data correspond to the months of August, September, and October 1989 for all the metropolitan areas. Conceptually, these data will reflect seasonal characteristics of demand for long distance service. In particular, some months of data collection correspond to the summer period, when the number of calls increases substantially. Accordingly, the $CALLS_{it}$ were normalized for seasonal variations.[9]

Calling data were aggregated by time of day (i.e., day, evening, and night calls), type of customer (i.e., residential and business subscribers), type of service (MTS, operator handled, person-to-person, private lines, etc.) and day of the week (i.e., weekdays and weekends). While this level of aggregation creates difficulties in studies that primarily seek to estimate the demand parameters for specific consumer groups or specific types of services, it does not affect our estimation because we are concerned with the aggregate effect of EAS.

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[8] Since the main interest of the study is to determine the economic impact of EAS, the data collection did not involve exchanges that were not affected by EAS. Thus, calls between, for example, a *NEW* exchange in the Memphis metropolitan area and a *NEW* exchange in the Nashville metropolitan area were not considered, since these calls were toll calls before and after EAS implementation.

[9] Monthly seasonal adjustment factors for intrastate toll calls in Tennessee were obtained from South Central Bell Telephone.

TABLE 1 Final Cross Sections By Metropolitan Area

Metropolitan Area	*CORE*	*NEW*
Memphis	Memphis/Arlington	Covington Moscow Somerville
	Collierville	Moscow Somerville
Nashville	Nashville/Old Hickory	Ashland City Gallatin Lebanon Murfreesboro Pleasant View Smyrna Springfield Watertown White House
	Goodlettsville	Gallatin Murfreesboro Springfield White House
Knoxville	Knoxville	Clinton Dandridge Gatlinburg Harriman Jefferson City Kingston Lake City Lenoir City Loudon Maryville Oak Ridge Oliver Springs Rockwood Sevierville White Pine
	Mascot/Solway	Dandridge Jefferson City
Chattanooga	Chattanooga/Soddy Daisy/Georgetown	Cleveland Dayton

Another level of aggregation, however, deserves comment. The implementation of EAS creates the possibility of cost savings on metering equipment by the local telephone carrier. Specifically, many of the metering devices installed in the affected exchanges were turned off after EAS adoption. As a result, the data for these particular exchanges were either lost through the elimination of the exchange from the sample or deliberately aggregated to other trunking lines that continued to be assisted by metering equipment. For example, in the Knoxville metropolitan area, the calls from the small exchange of Greenback to Knoxville were combined with the calls from Lenoir City to Knoxville. This reduced the sample size to a total of 148 observations, because the total number of cross-sectional units, N, dropped to 74 and $t = 1, 2$.

The data reveal a significant increase in the calling level after EAS implementation, which indicates a prompt consumer response to the price change. For example, the gross increase in the mean number of calls from the pre-EAS to the post-EAS period ranged from 337% in Chattanooga to 447% in Memphis. Statewide, for telephone exchanges affected by

EAS, the average increase in the number of calls was 379% between the pre-EAS and post-EAS observations. In contrast, the statewide growth rate of toll calls averaged 12.2% in the five years preceding the implementation of EAS.

3. Estimation issues and the empirical model

■ The raw response of observed calling patterns between exchanges affected by the EAS plan suggests a significant demand response from the introduction of EAS. To isolate the structure of consumer responses to the observed price changes, however, it is necessary to formally model the demand for interexchange calling between the affected exchanges. It is to this effort that we now turn.

The implementation of EAS across several metropolitan areas and data on calling patterns both before and after the introduction of EAS generate a pool of cross-sectional and time-series data. The most general specification of our demand model, then, can be given by

$$CALLS_{it} = \beta_{1it} + \sum_{k=1}^{s} \beta_{kit} x_{kit} + \varepsilon_{it}, \tag{1}$$

where x_{kit} is the kth nonstochastic variable associated with cross-sectional unit i in time period t; β_{1it} and β_{kit} are, respectively, the intercept and the slope parameters to be estimated, which may vary across time and cross-sectional units; and ε_{it} is an error term. Restrictions to this general specification are commonly placed on both the parameters and the specification of the error.[10] We specify three different parameter structures. The first, referred to as model 1, permits intercepts to be different for certain values of i but restricts them to be constant over time. Specifically, we account for the potential for systematic differences in the demand response to EAS across the *CORE* exchanges affected by the pricing change. The second specification, model 2, allows for cross-sectional differences on the slopes associated with a specific set of regressors while holding the intercept fixed. Finally, model 3 allows for variations on both the intercepts and the slope coefficients across *CORE* exchanges.

While the most common error-structure problems likely to arise in the context of cross-sectional time-series models are well known and relatively easy to deal with, a unique attribute of point-to-point telecommunications demand creates the prospect for an unusual error structure. Specifically, it is possible that increased (decreased) calling from x to z will alter (either up or down) the level of calling from z to x. While it is impossible *a priori* to determine the sign of this cross-exchange correlation, ρ_0, it is clear that failure to account for such correlation will undermine both parameter estimation and hypothesis testing.[11] Accordingly, we develop an estimation procedure designed specifically for this case that will lead to a feasible Aitken estimator of the parameter vector that is asymptotically equivalent to the Aitken estimator and therefore consistent and asymptotically efficient.[12]

[10] See Judge et al. (1985) for a survey of models that combine time-series and cross-sectional data.

[11] See Judge et al. (1985).

[12] See Martins-Filho and Mayo (1992). To our knowledge, all studies of point-to-point telecommunications demand, with one exception, have ignored the potential for cross-sectional correlation between transposed exchange pairs. Larson, Lehman, and Weisman (1990) accounted for this correlation by explicitly modelling demand in a simultaneous-equations framework, where calls from x to z are endogenously determined by calls from z to x and vice versa. While there is no theoretical reason to prefer our approach to theirs, data limitations point toward the attractiveness of the method developed herein. Specifically, because most (all) studies of point-to-point telecommunications demand combine a large number of cross-sectional units and a small number of time periods, the estimates of the simultaneous-equations approach may prove unreliable. Specifically, as Anderson and Hsiao (1982) have shown, the appeal to large sample consistency of cross-sectional time-series simultaneous-equation model estimates may be lost if relatively few time-series observations are observed.

TABLE 2 Variable Definitions and Pre-EAS Descriptive Statistics

		Mean (Standard Deviation)					
Variable	Definition	Statewide	Memphis	Knoxville	Nashville	Chattanooga	Source
PFMIN	Price of the first minute of a long distance call between exchanges x and z	.196 (.047)	.224 (.058)	.195 (.047)	.183 (.039)	.225 (.028)	[1]
PADMIN	Price of an additional minute for a long distance call between exchanges x and z	.167 (.036)	.186 (.045)	.166 (.036)	.159 (.031)	.190 (.011)	[1]
PCALL	Price paid for a call of average duration	.70 (.153)	.780 (.192)	.694 (.155)	.662 (.131)	.79 (.063)	[1]
N_x	The number of subscribers in exchange x	1.0×10^5 (1.3×10^5)	1.3×10^5 (2.0×10^5)	7.6×10^4 (7.6×10^4)	1.3×10^5 (1.6×10^5)	9.1×10^4 (8.3×10^4)	[1]
MARKET	The product of the number of customers in exchanges x and z, which is a proxy for market size	2.0×10^9 (2.6×10^9)	1.2×10^9 (1.4×10^9)	1.5×10^9 (1.7×10^9)	2.9×10^9 (3.5×10^9)	3.2×10^9 (2.4×10^9)	[1]
INCOME	Per capita income in exchange x less the fixed monthly charge	9575.9 (1337.0)	8938.5 (1160.5)	9211.6 (1393.6)	10352.8 (1006.3)	9216.4 (1180.9)	[2]
DISTANCE	The basis for a set of dummy variables representing mileage bands of various distances	26.1 (8.7)	30.8 (10.1)	26.4 (9.2)	23.0 (6.7)	31.5 (5.2)	[1]

Sources: [1] South Central Bell Telephone Company; [2] Bureau of the Census.

As suggested by the theory of telephone demand developed in Rohlfs (1974), Mitchell (1978), Taylor (1980), and the previous empirical literature[13] on demand estimation, several variables may serve as explanatory variables. Table 2 provides a description of the nonstochastic variables to be used in the estimation of the demand model, and it also provides statewide and metropolitan-area descriptive statistics on these variables.

Because the first-minute charge differs from the charge for additional minutes of calling, the price of a telephone call may be written as

$$PCALL_{it} = PFMIN_{it} + \Lambda PADMIN_{it}, \tag{2}$$

where $PFMIN_{it}$ is the rate for the first minute, $PADMIN_{it}$ is the rate for additional minutes, and Λ is a positive integer. Given that the pre-EAS average call duration was between three and four minutes, we let $\Lambda = 3$ for estimation purposes. Consistent with standard demand theory, we expect a negative coefficient associated with this variable.

Per capita income is also likely to affect the observed demand for point-to-point calling. To account for the approximate one-year gap between the pre-EAS and post-EAS observations on per capita income, the latter observations were deflated by the consumer price index. Additionally, while income effects associated with the fixed monthly charge are likely to be small, we subtract such charges from income levels to capture more accurately the influence of income on usage (as opposed to access) levels. Thus our regressor, $INCOME_{it}$, is the net real per capita income in the originating exchange pair.

The number of calls from x to z is also likely to be positively related to the number of subscribers in each exchange. If there are N_x and N_z subscribers in exchanges x

[13] See, *inter alia,* Deschamps (1974), Infosino (1980), de Fontenay and Lee (1983), and Pacey (1983). For a survey of the literature, see Taylor (1980).

and z, respectively, the total number of possible connections between x and z is given by $MARKET_i = N_x \cdot N_z$, which is used as a regressor representing market size. Because distance (d) is highly correlated with price in the case of telephone pricing, we chose to specify three different distance bands (in miles) and associate dummy variables $DISTDUM_{gi}$, $g = 1, 2, 3$, to each of them. Thus,

$$DISTDUM_{1i} = \begin{cases} 1 & \text{if } d \in (20, 30] \\ 0 & \text{otherwise} \end{cases} \qquad DISTDUM_{2i} = \begin{cases} 1 & \text{if } d \in (30, 40] \\ 0 & \text{otherwise} \end{cases}$$

$$DISTDUM_{3i} = \begin{cases} 1 & \text{if } d \in (40, 50] \\ 0 & \text{otherwise} \end{cases}.$$

Because consumers separated by larger distances are likely to have fewer reasons to interact than those in greater proximity, we expect negative signs on the coefficients associated with the distance dummies.

Consistent with prior empirical research on telecommunications demand, we specify a log-linear demand structure for the estimating model. Because the post-EAS prices and some distance variables are zero, however, we cannot impose the log transformation to all the independent variables. In such cases the variables enter the model untransformed. Thus, the final estimations take the form

$$\ln(CALLS_{it}) = f(PCALLS_{it}, \ln MARKET_{it}, \ln INCOME_{it}, DISTDUM_{1i}, DISTDUM_{2i}, DISTDUM_{3i}), \quad (3)$$

with the restrictions imposed on the model as described above, and where f is linear in its arguments.

4. Demand estimation results

■ The models were estimated both with ordinary least squares (OLS) and the feasible generalized least squares procedure developed in Martins-Filho and Mayo (1992). To generate estimated generalized least squares (EGLS) estimators, we first applied OLS to all models, obtaining residuals that were used to estimate ρ_0, the cross-exchange error correlation. The estimated value of ρ_0—i.e., $\hat{\rho}$—is then used to obtain $V(\hat{\rho})$, which provides a basis for the feasible Aitken estimator of β. Additionally, given the primarily cross-sectional nature of the data, we performed the Breusch and Pagan (1979) test for heteroskedasticity. The results indicate that we cannot reject the hypothesis of homoskedasticity. Table 3 reports the estimated value for the parameters in models 1–3 and their associated t-statistics, regression R^2s and the estimated value for ρ_0. The results are very encouraging. The models consistently have high explanatory power with R^2s over .91, and virtually all the individual parameters have the expected signs.

Consistent with our expectation, the coefficient on the price variable is negative and highly significant in all the estimated models. Given the estimated parameter values and the average pre-EAS values of the other variables, the pre-EAS price elasticity of demand generated by the estimations ranges from −1.05 to −1.55.[14] Such elasticities are generally consistent with, although somewhat higher than, the findings of earlier studies surveyed by Taylor (1980).

The variable reflecting the size of the market ($MARKET_{it}$) is also highly significant and has a positive coefficient. Thus, an important determinant of the demand for exchange-

[14] To gauge the plausibility of these elasticity estimates, which are measured at pre-EAS prices, we also estimated a series of constant elasticity (double-log) demand models using only positive price data drawn from the pre-EAS cross-sectional observations. The implied price elasticities, which ranged from −1.18 to −1.54, are consistent with those that result from use of the full sample.

TABLE 3 Demand Estimation Results

	Model 1		Model 2		Model 3	
Variable[a]	OLS	EGLS	OLS	EGLS	OLS	EGLS
$PCALLS_{it}$	−2.42*	−2.43*	−1.62*	−1.65*	−2.00*	−2.00
	(−21.45)	(−18.53)	(−4.96)	(−4.32)	(−4.92)	(−4.21)
ln $MARKET_{it}$	.773*	.774*	.696*	.699*	.781*	.782*
	(18.75)	(15.75)	(24.29)	(20.92)	(19.06)	(16.28)
ln $INCOME_{it}$	−.308	−.345	−.071	−.221	−.320	−.348
	(−1.14)	(−1.52)	(−.258)	(−.951)	(−1.20)	(−1.51)
$DISTDUM_{1i}$	−.464*	−.465*	−4.32*	−.440*	−.438*	−.440*
	(−4.62)	(−3.88)	(−4.33)	(−3.77)	(−4.41)	(−3.77)
$DISTDUM_{2i}$	−.766*	−.768*	−.771*	−.781*	−.729*	−.730*
	(−6.69)	(−5.60)	(−6.98)	(−6.04)	(−6.41)	(−5.46)
$DISTDUM_{3i}$	−.519*	−.523*	−.528*	−.549*	−.500*	−.502*
	(−2.74)	(−2.31)	(−2.77)	(−2.47)	(−2.67)	(−2.28)
Degrees of freedom:						
Model	12	12	12	12	18	18
Error	135	135	135	135	129	129
s^2	.175	.177	.199	.194	.171	.172
$\hat{\rho}$	—	.427	—	.427	—	.380
R^2	.924	.924	.914	.914	.930	.930

* Statistically significant at the 1% level.

[a] As described in Section 3, a set of variables was included to account for the possibility that the telecommunications demand structure varies across *CORE* metropolitan areas and/or over time. Because these variables are not of primary importance here, we omit these results from the table. These additional results are available from the authors upon request.

to-exchange calling is the number of potential connections between the exchanges. Consistent with prior empirical studies of toll demand, the parameter estimates on the income variable are insignificantly different from zero.[15] The coefficients on the distance dummy variables are significant in all the model specifications and have the expected sign. Finally, estimates of cross-sectional and intertemporal shifts in the demand structure (not reported) are varied, with some but not all of the coefficients taking on significance levels of note.[16]

In all models $\hat{\rho}$ is positive, taking values between .38 and .43 for models 1–3. This positive correlation between the errors in exchange pairs indicates that whenever there is a change in, say, $CALLS_{xz}$ due to its error term, there will be a corresponding positive change in $CALLS_{zx}$ via its error term. Numerically this increase will vary from 38% to 43%, depending on the model considered. The complementarity suggested by our estimates confirms equivalent results obtained by Larson, Lehman, and Weisman (1990), although the estimated "reciprocity" is lower in our case.

5. The economic welfare effects of EAS

■ Evaluation of the demand conditions for exchange-to-exchange telephone service identified in Section 4 provides a springboard from which it is possible to evaluate the economic welfare effects of alternative telephone pricing structures. In this section, we first develop a conceptual framework for evaluating the economic welfare effects of EAS. Next, we employ this framework and the empirical demand estimates generated above to calculate the consumer-surplus impacts associated with the introduction of EAS in Tennessee.

[15] See, for example, Infosino (1980). In contrast to our model, which relies upon per capita measures of income, models that rely on total income within the market area tend to generate significant parameters associated with the income variable. See, for example, Pacey (1983).

[16] Given the mixed significance levels of the cross-sectional and time-series slope and intercept coefficients, we tested the hypothesis of no cross-section demand variations across metropolitan *CORE* exchanges. The test performed, alternatively, for intercept and slope variations was rejected in nearly all model specifications.

□ **A framework for assessing the welfare effects of EAS.**[17] Let x and z be two different exchanges containing N_x and N_z subscribers respectively. Consider the demand for telephone calls between two subscribers a and b that lie in x or z. Specifically, let the demand for calls from a to b be denoted by $y_{ab}(p)$.[18] We can denote the total demand for local calls within x and z by $y_{xx}(0) = \sum_{a=1}^{N_x} \sum_{\substack{b=1 \\ a \neq b}}^{N_x} y_{ab}(0)$ and $y_{zz}(0) = \sum_{a=1}^{N_z} \sum_{\substack{b=1 \\ a \neq b}}^{N_z} y_{ab}(0)$. Similarly, the total demand for long distance calls between x and z can be denoted by $y_{xz}(p) = \sum_{a=1}^{N_x} \sum_{b=1}^{N_z} y_{ab}(p)$ and $y_{zx}(p) = \sum_{a=1}^{N_z} \sum_{b=1}^{N_x} y_{ab}(p)$.

The question at issue is whether the introduction of EAS between exchanges x and z is justified on economic welfare grounds.[19] The welfare associated with the pre-EAS price structure is represented by

$$W_0 = \int_0^\infty [y_{xx}(\gamma) + y_{zz}(\gamma)]d\gamma + \int_{p_1}^\infty [y_{xz}(\gamma) + y_{zx}(\gamma)]d\gamma - (L_xN_x + L_zN_z)$$
$$+ p_1[y_{xz}(p_1) + y_{zx}(p_1)] + L_xN_x + L_zN_z - c_1[y_{xx}(0) + y_{zz}(0)]$$
$$- c_2[y_{xz}(p_1) + y_{zx}(p_1)], \quad (4)$$

where γ is the dummy of integration, L_x and L_z are the fixed monthly subscription charges, p_1 is the level of prices for long distance calls pre-EAS, and c_1 and c_2 are the long-run marginal costs of providing local and long distance telephone service, respectively.[20] The first and second integrals in (4) correspond to consumer surplus from local and long distance calls, respectively; the third term in (4), i.e., $L_xN_x + L_zN_z$, represents the reduction in consumer surplus due to the flat monthly charge; $p_1[y_{xz}(p_1) + y_{zx}(p_1)]$ represents pre-EAS long distance revenues; and finally, $c_1[y_{xx}(0) + y_{zz}(0)]$ and $c_2[y_{xz}(p_1) + y_{zx}(p_1)]$ are the costs associated with providing local and long distance service, respectively.

There are two types of EAS, namely one-way and two-way EAS. In the first case, subscribers in x (z) can call subscribers in z (x) at a zero marginal price, but if consumers in z (x) decide to call consumers in x (z) they will pay toll rates. In the second case, all subscribers, in both x and z, face a zero marginal price for all calls within the (enlarged) LCA.

The economic welfare under one-way EAS benefiting exchange x can be represented by

$$W_1 = \int_0^\infty [y_{xx}(\gamma) + y_{zz}(\gamma) + y_{xz}(\gamma)]d\gamma + \int_{p_1}^\infty y_{zx}(\gamma)d\gamma - (L'_xN_x + L'_zN_z)$$
$$+ p_1y_{zx}(p_1) + (L'_xN_x + L'_zN_z) - c_1[y_{xx}(0) + y_{zz}(0) + y_{xz}(0)] - c_2y_{zx}(p_1). \quad (5)$$

[17] Dansby (1980) provides the seminal treatment of spatial dimensions of utility pricing.

[18] For notational simplicity, all variables other than price (p) that influence demand are suppressed, and $CALLS_{xz}$ are henceforth denoted y_{xz} for all x and z.

[19] Following conventional methodology, the sum of consumer surplus plus producer surplus is taken as the measure of economic welfare. See, for example, Brown and Sibley (1986) and Griffin and Mayor (1987).

[20] Since long distance calls are billed on a per-call basis, a variety of costs associated with metering equipment is incurred. Since this additional capital investment is not necessary for local calls, $c_2 > c_1$.

Under two-way EAS, economic welfare can be denoted by

$$W_2 = \int_0^\infty [y_{xx}(\gamma) + y_{zz}(\gamma) + y_{xz}(\gamma) + y_{zx}(\gamma)]d\gamma - (L'_x N_x + L'_z N_z) + (L'_x N_x + L'_z N_z) - c_1[y_{xx}(0) + y_{zz}(0)] - c_1[y_{xz}(0) + y_{zx}(0)]. \quad (6)$$

In both (5) and (6) the primes (′) indicate the possibility that the values observed under EAS pricing may differ from those in (4). Specifically, to the extent that the firm forgoes revenue on y_{xz} in the case of one-way EAS and also on y_{zx} in the case of two-way EAS, regulators may find it necessary to adjust L_x and L_z to satisfy the regulatory (and legal) constraint that profits be nonnegative. Equations (4), (5) and (6) combine to provide the change in economic welfare associated with the establishment of one-way and two-way EAS, given respectively by[21]

$$\Delta W_1 = \int_0^{p_1} y_{xz}(\gamma)d\gamma - (p_1 - c_2)y_{xz}(p_1) - c_1 y_{xz}(0) \quad (7)$$

and

$$\Delta W_2 = \int_0^{p_1} [y_{xz}(\gamma) + y_{zx}(\gamma)]d\gamma - p_1[y_{xz}(p_1) + y_{zx}(p_1)] + c_2[y_{xz}(p_1) + y_{zx}(p_1)] - c_1[y_{xz}(0) + y_{zx}(0)]. \quad (8)$$

If $\Delta W_1(\Delta W_2) > 0$, then the move to one-way (two-way) EAS is welfare enhancing and EAS pricing is preferred to current toll pricing. The signs of ΔW_1 and ΔW_2 will depend on (a) the increased consumer surplus arising from the price reduction on long distance calls, i.e., the two terms involving the integral signs in (7) and (8); (b) the loss in producer surplus due to the price reduction on long distance calls, i.e., $p_1 y_{xz}(p_1)$ in (7) and $p_1[y_{xz}(p_1) + y_{xz}(p_1)]$ in (8); and (c) the change in operating costs associated with the transition to EAS, i.e., $c_2 y_{xz}(p_1) - c_1 y_{xz}(0)$ in (7) and

$$c_2[y_{xz}(p_1) + y_{zx}(p_1)] - c_1[y_{xz}(0) + y_{zx}(0)]$$

in (8).

Notice that when considering alternative tariffs to current toll pricing, regulators are not restricted to EAS pricing. In fact, an obvious (at least to economists) alternative is marginal cost pricing.[22] Instead of a zero marginal EAS price, the consumer will face a tariff that is equal to the marginal cost of providing the call. In this case, the welfare differential associated with the tariff change can be represented by

$$\Delta W_3 = \int_{c_2}^{p_1} [y_{xz}(\gamma) + y_{zx}(\gamma)]d\gamma - (p_1 - c_2)[y_{xz}(p_1) + y_{zx}(p_1)]. \quad (9)$$

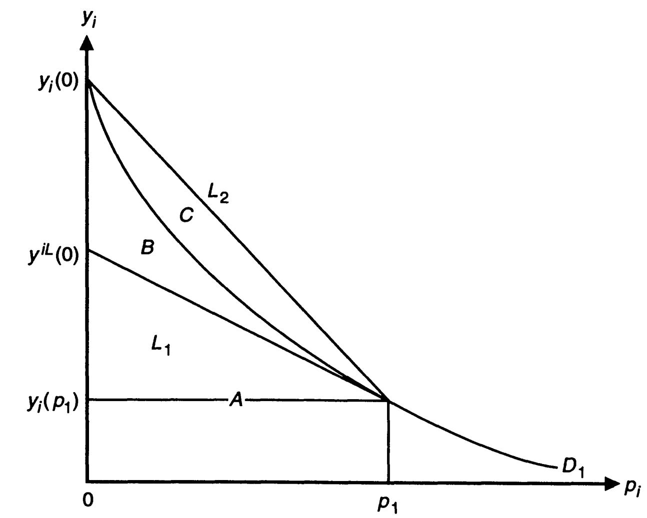
□ **The consumer-surplus impacts of EAS.** An important part of determining the economic merits of EAS revolves around the magnitude of the changes occurring in consumer surplus

[21] On the basis of prior empirical research on the demand for customer access to the telecommunications network, we assume that subscribership effects of implementing EAS are nil. See Taylor (1980), Perl (1983), and Kaserman, Mayo, and Flynn (1990). An extended discussion of subscribership effects in the context of EAS is contained in Martins-Filho (1992).

[22] In the presence of (particularly high) fixed costs, uniform marginal cost pricing may fail to generate revenues that allow the firm to cover its total costs. In this context, marginal cost pricing, which we consider here, together with a system of nondistortionary taxes remains the "first-best" pricing solution. Alternatives, not directly considered here, include "optimal" nonuniform prices and Ramsey prices. See Brown and Sibley (1986) for a discussion of these pricing alternatives.

FIGURE 1

UPPER AND LOWER BOUNDS OF THE WELFARE EFFECTS OF EAS FOR A REPRESENTATIVE EXCHANGE PAIR



when local calling areas are extended. Specifically, the larger the consumer-surplus benefits generated from the adoption of EAS, the more likely it is that the net economic welfare effects (i.e., including the change in producer surplus) will be positive. Accordingly, we now turn to a calculation of the changes in consumer surplus stemming from the implementation of EAS.

The nonlinearity of the demand dictates a careful analysis of the calculations involved in the welfare equations. Specifically, Figure 1 depicts a convex demand function for toll calls, where the number of calls (y_i) is represented on the vertical axis and a price variable (p_i) is depicted on the horizontal axis.[23] Our objective is to evaluate the integral

$$\int_0^{p_1} y_i(p)dp, \tag{10}$$

which provides a point estimate of the consumer-surplus gains brought about by the implementation of EAS. However, there are no observations on the level of prices for the interval $(0, p_1)$, where p_1 is the pre-EAS level of prices. Hence, the shape of D_1 in this interval is only suggested by the observed data. Since the curvature of D_1 in this range is unknown, it is possible that a straightforward extrapolation of the estimated demand function could overstate or understate the consumer surplus gained by implementing EAS. It would therefore be desirable to provide upper and lower bounds on the estimated change in consumer surplus. Specifically, we construct a linear segment (L_2) from $y_i(0)$ to $(p_1, y_i(p_1))$. Because the demand function is assumed to be convex, it lies below L_2 for all $p \in (0, p_1)$. Thus, convexity of the demand function in the interval $(0, p_1)$ guarantees that the area $A + B + C$ is an upper bound (B_{ui}) on the consumer gains from EAS. Similarly, we construct L_1 by locating the slope of the tangency of the demand function at p_1 and extending the segment to the ordinate axis. Again, by convexity, the demand function lies above L_1 for all $p \in (0, p_1)$. Thus, the area represented by A constitutes a lower bound (B_{li}) for the estimated value of EAS for exchange pair i.

Results of the demand estimation provide the specific basis to generate lower and upper bounds, as well as point estimates, of the consumer-surplus effects of EAS implementation.

[23] Recall that i represents an exchange pair as described in Section 2.

Specifically, the EGLS estimates of the previous section are used to locate the demand function for each pair of exchanges in $\mathbb{R}^2$ space. For a representative pair i, we have

$$\hat{y}_i = \exp[\hat{\alpha}_i + \beta_p p + .5 V_{\widehat{\ln y_i}}(p)], \tag{11}$$

where $\hat{y}_i$ is the estimated value for the number of calls for pair i, $\hat{\alpha}_i$ is the estimated intercept term for the demand function of pair i in $\mathbb{R}^2$, which includes the effects of the nonprice variables by substituting the observed exchange specific values of these variables into the estimated demand function; β_p is the estimated parameter for the price variable; and $V_{\widehat{\ln y_i}}(p)$ denotes the estimated variance of $\widehat{\ln y_i}(p)$ evaluated at p. (See, for example, Goldberger (1968) and Dadkhah (1984).) Given (11), we can represent the change in consumer surplus for the representative pair by

$$\int_0^{p_1} \hat{y}_i(p)dp, \tag{12}$$

which can easily be evaluated. The estimated gain in consumer surplus for all exchanges involved, i.e., the gains in consumer surplus generated by the implementation of two-way EAS, is given by

$$\Delta cs = \sum_{i=1}^{N} \int_0^{p_1} \hat{y}_i(p)dp. \tag{13}$$

While (13) provides a point estimate of the gains in consumer surplus resulting from the implementation of EAS, it is also possible to generate upper and lower bounds (B_u and B_l respectively) on the point estimate. For pair i we can write

$$B_{ui} = 0.5 p_1 \exp(\hat{\alpha}_i)[\exp(.5 V_{\widehat{\ln y_i}}(0)) - \exp(\beta_p p_1 + .5 V_{\widehat{\ln y_i}}(p_1))], \tag{14}$$

where p_1 is the observed pre-EAS price level for exchange pair i. Hence, consumer gains with EAS implementation will be bounded above by

$$B_u = \sum_{i=1}^{N} B_{ui}. \tag{15}$$

To obtain B_l, first consider the equation

$$(y_i)' = \beta_p \hat{y}_i(p_1), \tag{16}$$

which denotes the slope of the demand function for exchange pair i evaluated at pre-EAS price levels. We then project a linear demand function (denoted by y^{iL}) with equal slope from the point $(p_1, \hat{y}_i(p_1))$ to $(0, y^{iL}(0))$. We can then write

$$B_{li} = 0.5 p_1[y^{iL}(0) - \exp(\hat{\alpha}_i + \beta_p p_1 + .5 V_{\widehat{\ln y_i}}(p_1))], \tag{17}$$

where $y^{iL}(0)$ is the value of y^{iL} at $p_i = 0$. Hence consumer gains with EAS implementation are bounded below by

$$B_l = \sum_{i=1}^{N} B_{li}. \tag{18}$$

Geometrically, (15) and (18) represent the summation over all exchange pairs of the areas A and $(A + B + C)$ in Figure 1, respectively.

Table 4 presents the annualized estimates of B_l, Δcs, and B_u for models 1, 2, and 3. The last three rows in Table 4—one-way EAS (*CORE*), one-way EAS (*NEW*), and marginal cost pricing—present the changes in consumer surplus associated with hypothetical price movements. In one-way EAS (*CORE*), we assume that one-way EAS was introduced

TABLE 4 Annualized Changes in Consumer Surplus Under Different Pricing Options (Million $)

	Demand Model		
Pricing Option	(1)	(2)	(3)
Two-way EAS			
B_l	36.3	37.6	36.5
Point estimate	86.6	80.7	66.8
B_u	104.4	102.5	97.4
One-way EAS (*NEW*)	43.3	40.4	33.4
One-way EAS (*CORE*)	43.3	40.4	33.4
Marginal cost pricing	62.0	58.8	50.1

assisting only the *CORE* exchanges; therefore, for every i, if $x \in CORE$, consumers can call $z \in NEW$ at zero marginal price, but a call from z to x is a toll call. In one-way EAS (*NEW*), we assume that one-way EAS benefited $x \in NEW$ rather than $x \in CORE$. In these two cases, the change in consumer surplus for exchange pair i is given by (7), but for exchange pairs in which $x \in CORE$ ($x \in NEW$), the value of (7) will be zero under one-way EAS (*NEW*)(*CORE*). The aggregated change in consumer surplus in both cases is obtained by summing the estimated values of (7) over i. Finally, in marginal cost pricing we assume that prices moved from pre-EAS price levels to marginal cost levels.[24] Hence, the change in consumer surplus for exchange pair i is given by

$$\int_{c_2}^{p_1} \hat{y}_i(p)\,dp, \tag{19}$$

which corresponds to the first term in equation (9). The sum of (19) over all i's provides aggregate estimates of the change in consumer surplus.

Clearly, the net economic welfare impact of EAS depends not only on changes in consumer surplus, but also on any changes in producer surplus that may arise from the implementation of EAS. As considered in the theoretical framework developed above, the change in producer surplus brought about by EAS originates from the revenue losses due to the price reduction of what were formerly toll calls and the change in operating cost brought about by the adoption of EAS. A detailed account of the methodology and data necessary to determine the changes in producer surplus associated with EAS is available upon request. Here we simply note that for the case of Tennessee, the annual producer-surplus losses associated with two-way EAS ranged from $44 to $46 million, depending on the particular model specification. Thus, the traditional measure of economic welfare, the summation of consumer surplus and producer surplus, is generally positive.[25] For the EAS plan adopted in Tennessee, the estimated net annual welfare gains (associated with our point estimates of consumer surplus) for two-way EAS varied from approximately $22 million in model 3 to $41 million in model 1.

6. Caveats and extensions

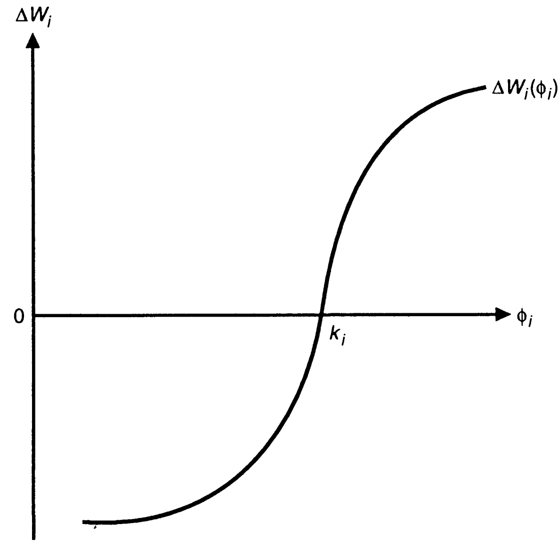
■ Although the welfare estimates associated with EAS implementation presented above are significant for both their existence and their magnitude, it is very important not to unduly extrapolate these results. For instance, the revealed increase in welfare due to im-

[24] The methodology to determine marginal cost levels is available upon request from the authors.

[25] The sole instance in which the net welfare change associated with EAS is negative occurs in the case of the lower bound estimates of consumer surplus.

FIGURE 2

THE RELATIONSHIP OF PRE-EAS PRICE-COST MARGINS AND THE WELFARE CHANGES FROM IMPLEMENTING EAS



plementation of EAS cannot be used as an outright basis upon which to recommend pricing telephone service at flat rates rather than measured service because in our case we do not compare an *optimal* pre-EAS tariff design to flat-rate pricing post-EAS. Indeed, extant studies that have assessed the economic welfare effects of measured service do exactly such a comparison (e.g., Griffin and Mayor (1987)), wherein the welfare associated with flat-rate local pricing is compared to the welfare levels generated by an alternative tariff designed to be welfare maximizing, given demand parameters and marginal cost characteristics. Therefore, while we find that flat-rate pricing under EAS tends to dominate existing toll tariffs, we cannot rule out the possibility (indeed, the likelihood) that there are pricing options that dominate the welfare generated by EAS.

Also, as is easily seen from equation (8), the larger the difference between pre-EAS toll prices and marginal cost, the larger will be the economic welfare gains from EAS pricing. Thus, when consumer surplus and producer surplus are summed, any positive welfare gain that may appear from EAS implementation is likely to be sensitive to some degree to the original distortions to economic welfare caused by toll prices with high-price marginal cost margins. Specifically, if we let price minus marginal cost for exchange i be φ_i, then the relationship between $\Delta W_i(\varphi_i)$ and φ_i can be seen in Figure 2.[26] Notice that there exists a $k_i > 0$ such that if $\varphi_i > k_i$ then $\Delta W_i(\varphi_i) < 0$. This indicates that at high pre-EAS toll rates, EAS will be welfare enhancing, while with lower toll price markups, implementing EAS will be welfare reducing.[27]

Finally, because our welfare estimates abstract from several other considerations that may affect the public-policy merits of embracing EAS, two additional caveats should be noted. First, given that the implementation of EAS enables local telephone companies to serve a possibly quite large share of the short-haul toll market at a zero price, EAS will preempt the possibility of competition for these calls. Specifically, even if regulators permit

[26] We have plotted this graph for models 1, 2, and 3. While the shape of $\Delta W_i(\varphi_i)$ is the same, the value of k_i varies with the specific model considered.

[27] This result was anticipated by Wenders (1987).

intraLATA competition from alternative long distance carriers, those carriers will be unable to compete with the prevailing zero marginal price.[28] Under these conditions the long-term effects of EAS pricing on welfare may be attenuated or reversed. Second, it is possible that EAS may have an effect on the availability and price levels of other services offered by the local telephone company. Specifically, the loss in revenues brought about by EAS pricing may well be large enough so that the $\pi \geq 0$ regulatory constraint is violated. In that case, the state public utilities commission will be forced to adopt a new rate structure in which other services provided by the local telephone company will be subject to rate increases, so that the regulatory constraint is once again met. These other services may or may not be confined to the exchanges affected by EAS; in fact, it has often been the case that the financial consequences of EAS plans have been distributed over the entire jurisdiction (state) of the public utilities commission.[29] Under this scenario, a pattern of cross-subsidization in which consumers in isolated exchanges (not benefiting from any type of EAS pricing) transfer resources to consumers in EAS areas. Although the use of cross-subsidization to attain specific socioeconomic goals has been an integral part of the history of telephony in the United States, such a pattern does not seem to fulfill any societal goal. Furthermore, to the extent that consumers outside the EAS area are affected by price increases, the overall welfare effect of EAS pricing becomes uncertain.

7. Conclusion

■ There are a number of unanswered economic questions about the observed geographic patterns of pricing telephone services. Prominent among them are the ones concerning the demand response and welfare consequences of extended area telephone service. In this article we have developed a demand model and framework to address these questions. Moreover, the recent implementation of an EAS plan in the metropolitan areas of Tennessee provided us with a unique opportunity to develop empirical estimates of the magnitude of the changes in both demand response and consumer surplus associated with EAS.

The empirical results indicate that demand is quite responsive to the implementation of EAS and that the consumer-surplus consequences of EAS are quite significant. But these results are shown to be sensitive to, among other things, the level of price-cost margins prevailing prior to the implementation of EAS.

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[28] Since the implementation of EAS enables local telephone companies to serve a substantial share of the intraLATA long distance market at zero price, EAS may play the role of a strategic action that preempts future competition in intraLATA markets. In fact, various states that allow intraLATA competition have instituted EAS pricing, therefore effectively eliminating competition on the exchanges affected by the plan.

[29] Examples of this widespread distribution of costs include the EAS plans introduced in Missouri (Kansas City and St. Louis) and Florida (various exchange pairs affected).

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