

Low-Income Demand for Local Telephone Service:
The Effects of Lifeline and Linkup*

Daniel A. Ackerberg
University of California at Los Angeles

Michael H. Riordan
Columbia University

Gregory L. Rosston
Stanford Institute for Economic Policy Research

Bradley S. Wimmer
University of Nevada, Las Vegas

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Abstract:

A comprehensive data set on local telephone service prices is used to evaluate the effect of Lifeline and Linkup programs on the telephone penetration rates of low-income households in the United States. Lifeline and Linkup programs respectively subsidize the monthly subscription and initial installation charges of eligible low-income households. This is the first study to use specific rates for telephone service faced by low-income households to explain the telephone penetration rates of low income populations at different locations. Telephone penetration rates are explained by an estimated nonlinear function of local service characteristics (including subsidized prices) and of the demographic composition of low-income populations. This empirical specification is based on an underlying discrete choice model of household demand for telephone service and an exact aggregation across demographic groups. A generalized method of moments (GMM) estimator corrects for endogenous service characteristics and for clustered residuals. The resulting estimated price elasticity of demand for telephone service is about -0.05, and a policy simulation predicts that low-income telephone penetration rates would be about 5% lower without Lifeline and Linkup programs. The analysis also suggests that Linkup may be more cost-effective than Lifeline, and that low-income penetration would increase significantly if all states were to automatically enroll eligible households in Lifeline and Linkup programs.

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Introduction

“Universal service” has at least nominally been a concern of telecommunications regulators for quite a while. Usually this concern is directed at two different (but somewhat overlapping) groups: rural and low-income households. Our focus in this paper is on low-income households and the economic characteristics that affect their decisions to subscribe to telephone service. In this way, it may be possible to shed some light on the question of the effectiveness of policies that have been adopted to increase the telephone penetration of low-income households. These issues are important for current telephone subsidy programs, but also to shed light on the debate about how subsidy programs might work for Internet access in the future.

Overall telephone penetration in the U.S. is quite high – over 95% according to the 2003 FCC “Penetration Report.” (Belinfante, 2003) This same report shows that penetration rates are significantly lower for low-income households. Only 89% of households with income less than \$10,000 in 1984 dollars (\$17,427 in 2002) had a working telephone in their households according to the Penetration Report. The report also shows that low-income penetration rates differ substantially across states, ranging from 96.5% in Maine (compared to 98.2% of all households) to under 80% in Mississippi (compared to 90.9% of all households).

The FCC has two programs designed to increase the penetration rates of low-income households. The Lifeline program, started in 1985, provides a subsidy that reduces low-income subscribers’ monthly charges. The Linkup program reduces the initial hookup fee low-income households pay to establish telephone service. Both federal programs work in concert with state-level low-income programs. The FCC, in its

implementation of the universal service portions of the Telecommunications Act of 1996 (“Act”), dramatically increased the size of its Lifeline subsidy. Prior to the Act, the federal Lifeline program waived the federal subscriber line charge (SLC), which was equal to \$3.50 in most jurisdictions, as long as states matched this by lowering intrastate rates. The current Lifeline program provides all low-income customers in all states a baseline support equal to the federal SLC plus \$1.75, for a total of \$5.25 in all jurisdictions in 2000 with the exception of the District of Columbia where the federal SLC was less than \$3.50.¹ Lifeline customers receive additional federal support equal to one half of any support provided by an intrastate program, up to \$7.00 in total federal support. In states that take full advantage of the matching federal program Lifeline customers receive a subsidy of \$10.50.² The federal Linkup program reduces low-income subscribers’ initial connection charge by 50 percent of the customary charge, or \$30, whichever is less.³ The level of federal Linkup support was unaffected by the FCC’s implementation of the 1996 Act.

Several studies have examined the effect Lifeline and Linkup programs have on penetration rates.⁴ The majority of studies have used state-level data that include variables on the size of Lifeline and Linkup programs as explanatory variables in regressions that estimate the overall penetration rate in a state. For example, Garbacz and

¹ The size of the baseline support has risen in recent years because the cap of the federal SLC for residential customers has increased.

² Again, the size of federal support has increased since 2000 with increases in residential SLCs.

³ These programs are funded by taxes on telecommunications services. To the extent that low-income households are heavy users of the services taxed (e.g. long distance), the overall price reduction is less. We recognize that marginal subscribers are not likely to be heavy users of the taxed services, so low-income telecommunications users presumably experience a price decrease. See Hausman, Tardiff and Belinfante (1993).

⁴ See Riordan (2002) for a more complete background on the economics of universal service.

Thompson (2002, 2003) use state-level data from the 1970, 1980, 1990 and 2000 decennial censuses to estimate penetration rates. Erikson, Kaserman and Mayo (1998) use state-level data from the current population survey (“CPS”), which is available more frequently than the census, to conduct their study. Both of these studies find that Lifeline and Linkup programs have a statistically significant small impact on penetration rates. Garbacz and Thompson (2003) find that the demand for local service is highly inelastic (-0.006 to -0.011 in 2000) and that Lifeline and Linkup programs have little effect on penetration, estimating that a 10 percent increase in Lifeline and Linkup expenditures would add only about 20,000 households to the network in 2000. Erikson, Kaserman and Mayo (1998) find that targeted low-income subsidies affect state-level penetration rates positively, while untargeted subsidies do not have a statistically significant impact on penetration rates.

Studies that rely on statewide data use statewide-average residential prices as an independent variable. Because residential service prices can vary substantially within states, the use of statewide data masks substantial information. For example, in California, monthly rates for 100 calls a month for Lifeline customers vary from \$5.01 to \$6.90 and for non-Lifeline customers vary from \$11.62 to \$15.51.

Crandall and Waverman (2000) use location-specific price data obtained from incumbent local exchange carriers (ILECs) and data from the 1990 census for 1,897 different towns or places. They use both the price of local service and the Lifeline rates as explanatory variables in different regressions, as well as a dummy variable if the state has a Lifeline or Linkup plan interacted with the poverty rate to try to measure whether poor communities in states with Lifeline and Linkup programs have higher penetration

rates than poor communities in other states. They find no significant effect for Lifeline programs, which is consistent with their finding that there is little price elasticity of demand for telephone service overall.

Crandall and Waverman find that higher first-time connection charges reduce penetration rates, estimating an elasticity of penetration with respect to the charge for connecting a new subscribers ranges from -0.025 to -0.030. Surprisingly, they find that states with a Linkup program have lower penetration rates. The counterintuitive Linkup effect, they argue, may be due to the use of a dummy variable where only two states did not have a Linkup program in 1990. Perhaps more important, Crandall and Waverman note that the Linkup result may be caused by a reverse-causation problem because states that have high penetration rates may choose not to participate in federal low-income programs. Earlier works by Perl (1984) and Cain and McDonald (1991) indicate the possibility that the elasticity of demand is higher for low-income households.

Our study differs from previous work in two important ways. First, we estimate the distinct demand for telephone service of poor households, using geographically disaggregated data on Lifeline and Linkup service plans, a dummy variable indicating whether eligible households are automatically enrolled in these plans, characteristics of the telephone service available, and demographic characteristics of households. A virtue of restricting attention to poor households is that implicitly we allow the price elasticity of demand for low income populations to differ from the rest of the population. Second, our estimation controls for the possible endogeneity of Lifeline and Linkup discounts, as well as automatic enrollment, by using additional data on costs of service and state level political and demographic variables as instruments. Otherwise, uncontrolled for

demographic and service characteristics potentially bias our demand estimates, resulting in misleading conclusions about the effectiveness of low-income support programs.

Our empirical analysis uses data on connection and monthly subscription prices facing households eligible for Lifeline and Linkup programs, and on the characteristics of relevant service plans. Data on prices and service characteristics, obtained from Bell Operating Company (BOC) tariffs, are matched to more than 8,000 census places. The rich dataset, and our exclusive focus on poor populations, allows us to estimate the price elasticity for low-income households, which is employed to estimate of the effectiveness of low-income universal service programs. As suggested by Crandall and Waverman, our analysis also demonstrates that it is important to control for the endogeneity of prices, which reflect the size of low-income subsidies.

Our results show that Lifeline and Linkup programs increased the telephone penetration of poor households by 4.9%, with a 95% confidence interval between 2.92% and 6.98%.

Theory and Empirical Specification of Household Telephone Demand

Telephone service enables a household to place and receive calls. The value of telephone service to a representative household is assumed to be additively separable in the characteristics of the service. That is, a representative household is willing to pay an amount $e^t V$, where t describes the household, and V describes the nature of the service. If the price of telephone service is R , then the household elects service if $e^t V \geq R$, or equivalently, if $t \geq \ln R - \ln V$.

Consider a population of households described by a cumulative distribution function $F(t)$. The share of households who demand the service (penetration rate) at price R is

$$S = 1 - F(\ln R - \ln V). \quad (1)$$

Next, partition the population into M groups, indexed $g = 1, \dots, M$. Let X_g denote the population share of group g , and $F_g(t)$ the distribution of t for group g . Then telephone penetration of group g is $S_g = 1 - F_g(\ln R - \ln V)$, and the penetration rate of the whole population is

$$S = \sum_{g=1}^M X_g S_g. \quad (2)$$

Finally, assume that the distribution of household types within any group is exponential, with $F_g(t) = 1 - e^{-\lambda(t - \mu_g)}$ and $t \geq \mu_g$, where μ_g is a group-specific parameter.

It follows that $S_g = e^{-\lambda(\ln(R/V) + \lambda\mu_g)}$ and $S = e^{-\lambda(\ln(R/V))} \sum_{g=1}^M X_g e^{\lambda\mu_g}$. Alternatively, the penetration of the entire population is explained by the logarithmic equation

$$\ln S = -\lambda \ln R + \lambda \ln V + \ln \left(\sum_{g=1}^M e^{\lambda\mu_g} X_g \right). \quad (3)$$

This model of community demand for telephone service is the basis of our empirical specification. The price elasticity of demand for service is given by the parameter λ . A noteworthy simplifying assumption is that all population groups have the same price elasticity. Group differences in demand are captured purely by the parameters (μ_1, \dots, μ_M)

Our empirical model allows for locational variation in population and service characteristics. Thus, a basic unit of observation is a population of consumers at location

l . A vector of group shares (X_{1l}, \dots, X_{Ml}) describes each population, and the penetration rate at location l is

$$\ln S_l = -\lambda \ln R_l + \lambda \ln V_l + \ln \left(\sum_{g=1}^M \beta_g X_{gl} \right) \quad (4)$$

where $\beta_g = e^{\lambda \mu_g}$. Both the price (R_l) and nature of service (V_l) vary across locations.

Our empirical model must deal with the fact that telephone service typically requires a monthly subscription price (P_l) and a one-time installation charge (I_l). If the household monthly “amortization rate” is α , then $R_l = P_l + \alpha I_l$ and

$$\ln S_l = -\lambda \ln(P_l + \alpha I_l) + \lambda \ln V_l + \ln \left(\sum_{g=1}^M \beta_g X_{gl} \right). \quad (5)$$

We assume that this amortization rate, like the price elasticity, is constant within the

It remains to control for differences in the nature of service at different locations such as the number of people within the local calling area. Let Z_l denote a vector of variables controlling for the characteristics of the service at location l . Then

$$\lambda \ln V_l = \Gamma(Z_l) + \varepsilon_l, \text{ and}$$

$$\ln S_l = -\lambda \ln(P_l + \alpha I_l) + \ln \left(\sum_{g=1}^M \beta_g X_{gl} \right) + \Gamma(Z_l) + \varepsilon_l$$

An alternative way to write this is

$$\ln S_l = \ln \beta_1 - \lambda \ln(P_l + \alpha I_l) + \ln \left(X_1 + \sum_{g=2}^M \frac{\beta_g}{\beta_1} X_{gl} \right) + \Gamma(Z_l) + \varepsilon_l$$

So far, the left-hand-side variable has the interpretation of an expectation conditional the right-hand-side variables. The realized penetration rate will include an additional error term that could depend on unobservable demographic characteristics.

We specify a functional form for $\Gamma(\cdot)$ after we discuss the data and define Z_i . Unobservable characteristics of the service are summarized by the random variable ε_i . We recognize that the demand for telephone service may depend on characteristics of the locations, and, for this reason, include location characteristics in the vector Z_i . A policy variable we include in Z_i is whether a state automatically enrolls households in low-income support programs. Other included policy variables are the size of the local calling area and the access rate for intrastate long distance calls.

The main parameters of interest are λ and α . The parameter λ is the elasticity of household demand with respect to the household's monthly service price, while α is the discount rate for the installation charge. Estimates of these parameters enable us to gauge the effect of Lifeline and Linkup discounts on the penetration rates of low-income populations, holding service characteristics constant.

Data

The data for the analysis come from a variety of sources: the 2000 decennial census, state-level telephone tariffs, the FCC (2000) Hybrid Cost Proxy Model, and Telcordia's (2000) Local Exchange Routing Guide (LERG). The data include information on telephone penetration rates and demographics, the price of basic local telephone service, connection charges, Lifeline and Linkup discounts, other information from state tariffs and estimates of the cost of providing local service. The data set includes 9,060 census places located in 43 states and the District of Columbia in the original BOC regions,⁵

⁵ Excluded states are Alaska, Hawaii and Connecticut, which are not served by BOCs, Delaware, which is not included in the FCC HCPM, and Montana, Wyoming and Vermont, which have different prices for households served by each switch depending on the distance from the switch so that it was impossible to

representing approximately 50 million residential access lines. FCC ARMIS data and the HCPM indicate that the Lifeline program subsidized approximately 5 percent of the lines in our data in 2000.

The dependent variable is the natural log of a census place's penetration rate for households below the poverty level (*Penetration*),⁶ which comes from the census and is equal to the ratio of the number of low-income households where a telephone is available to the number of low-income households.⁷ For our purposes, a low-income household is one below the poverty line.

Because data on local prices and other data from state tariffs are reported by wire center,⁸ we matched wire centers to census block groups using Claritas (2003) data. Since local monthly prices are given by wire center and places in relatively urban areas are served by multiple wire centers, rates are not always uniform within a census place. Places with non-uniform Lifeline rates are not included in the study because we are unable to determine the rates faced by the low-income households in such places.

The independent variables of primary interest are the monthly charge for local service and the charge for connecting to the network. Because low-income households

accurately determine the prices faced by low income households. Southern New England Telephone company, which provides service in Connecticut, was purchased by SBC following passage of the Telecom Act of 1996.

⁶ Census places are either "incorporated areas" (like cities) or "census designated palaces" that are a separately identified concentration of population.

⁷ The census defines a telephone as being available when a household has a telephone in working order and is able to make and receive calls. Households whose telephone service has been discontinued for nonpayment or any other reasons are counted as not having a telephone available (see, Census Bureau, 2000 sf3 documentation).

⁸ A wire center includes all customers connected to a particular local switch. In metropolitan areas several wire centers serve a single census place, while in rural areas, a single switch may serve multiple census places.

are the focus of this study, data on charges to customers eligible for Lifeline and Linkup are used. In the majority of states, low-income customers can choose from a variety of local-service offerings. Customers may subscribe to a usage-based plan, where they pay for each call or minute of local use in addition to a monthly charge. Customers subscribing to a flat-rated plan pay only the monthly charge and are allowed to make an unlimited number of local calls. The majority of the states in the sample offer subscribers both flat-rated and usage-based plans. Only Wisconsin and portions of New York (NYC) and Illinois require that consumers subscribe to a usage-based plan, while Kansas, Kentucky, North Carolina and Maine do not offer usage-based options.⁹ For the empirical work, the variable *Lifeline100* is the minimum monthly expenditure of Lifeline customers making 100 local calls.¹⁰ The other variable of primary interest is *Linkup*, which is equal to the connection charge paid by customers eligible for the Linkup subsidy.

The FCC Penetration Report indicates that penetration rates for Blacks and Native Americans are lower than average while those for Asians are higher. To control for possible ethnic differences in the demand for telephone service we include the variables, *Whites*, *Blacks*, *Native Americans*, *Asians* and *Other Non-whites* which are equal to the percentage of the population that is below the poverty level and belongs to the respective ethnic group.

⁹ Vermont also requires a usage-based plan, but is not included in our dataset. Washington requires Lifeline customers subscribe to a flat-rated plan, while Maryland, Arkansas and West Virginia require Lifeline customers subscribe to a usage-based plan. In each of these states non-Lifeline customers may subscribe to either flat-rate or usage-based plans.

¹⁰ *Lifeline100* is the minimum basic monthly access charge plus usage charges across all available plans assuming the customer completes 100 local calls. The access charge component equals the non-Lifeline monthly charge, including the federal SLC, less the total Lifeline discount. *Lifeline* includes extended area of service surcharges when such surcharges are non-optional.

An important characteristic of the service provided is the number of people within a customer's local calling area (LCA). Customers with flat-rated service can make an unlimited number of calls to customers located within their LCA. When subscribing to a usage-based plan, the rates for local calls are lower than charges for calls outside the customer's LCA. *Local Calling Area* is equal to the number of households within a customer's local calling area. Tariff data were used to identify the localities included in each wire center's LCA. Claritas (2003) data and data from the census were then used to calculate the number of households within each wire center's LCA.¹¹ We expect a positive relationship between *Local Calling Area* and *Penetration*, holding other factors constant.¹²

Intrastate access charges are included to capture the effect the price of calls outside the customer's LCA has on penetration.¹³ Intrastate access charges are the fees that local exchange carriers charge long-distance companies for completing non-local intrastate calls. The variable *Access4*, which is equal to access charge for a four-minute intrastate long-distance call, is expected to receive a negative coefficient.¹⁴

¹¹ In places served by more than one wire center, the household-weighted average LCA is used for the place.

¹² Many states use value-of-service pricing, where local rates are directly related to the size of a customer's LCA.

¹³ Because customers make both local and long-distance calls, the price of long-distance calls affects subscriber decisions. See Hausman, Tardiff, and Belinfante (1993).

¹⁴ The access charge used includes charges for originating and terminating minutes for carrier common lines charges, switched access, transitional and call-set up charges, along with any charges for state universal service programs. In New Jersey, Maryland, Virginia and West Virginia, the CCLC is determined by a long-distance carrier's share of total intra-state long-distance minutes. In these states, the state commission determines the total amount of money to be recovered through the CCLC and charges carriers on a retroactive basis. We estimate the CCLC in these states using ARMIS and tariff data.

We include only intrastate access charges because interstate long-distance prices in states do not reflect the each state's interstate access charge. Section 254(g) of the Telecommunications Act forbids long distance carriers from charging different rates in different states, even if the states have different costs. As a result, there would be little basis for inclusion of interstate access charges, and we do not have the requisite information to determine if there is a systematic difference in actual retail rates paid by consumers in different places.

Some states have programs that automatically enroll a household for lifeline rates if the household is on public assistance. The dummy variable *Autoenroll* is equal to one if the state has an automatic enrollment program. Given that some low-income households may not be aware of the lower lifeline rates, this program would be expected to increase low income penetration by effectively reducing the price. Information of these projects comes from a survey conducted by Center for Media Education/Center for Policy Alternatives (1999). The survey lacked information about Alabama, Arizona, Louisiana, Missouri, Nevada and Virginia.¹⁵ This reduces our data to 8,120 observations.

The last variable included to control for service characteristics is *Rural Percent*, which is equal to the percentage of households within a census place living in what the census classifies as a rural area. A plausible hypothesis is that the value of a telephone service is higher for customers living in rural areas because face-to-face communication is more difficult. The variable, however, might also serve as a proxy for other characteristics, suggesting that the sign of coefficient on this variable is difficult to predict *a priori*.

¹⁵ We have since learned that among these states only Nevada had an automatic enrollment plan in place at the time of the 2000 census.

We control for the possibility that weather influences the demand for telephone services with an estimated quadratic function of the average temperature (*Temperature*) and average precipitation (*Precipitation*) in each locality. The quadratic forms allows for nonlinearities in how these weather variables matter for telephone demand.¹⁶

Finally, we employ several “instruments” in the GMM models to control for the possible endogeneity of *Lifeline100*, *Linkup*, and *Autoenroll*. These include the forward-looking cost of service at local and state levels (*Cost* and *State Cost*), obtained from the FCC’s Hybrid Proxy Cost Model, and a variety of political variables. The variable *State Cost* is expected to increase prices because state regulators are required to set rates that recover the carrier’s cost of service. We also include variables that capture whether state public utility commissioners are elected or appointed (*PUCElect*), percentage of state legislator that are democrats (*Democrat Ratio*), the ratio of business to residential lines in 1999 (*Bus/Res Ratio*), and the percentage of a state’s population that is below the poverty level (*State Poor*). Also included as instruments are state-level variables for the ethnicity variables and *Rural Percent* variables discussed above.

Our reason for treating only *Lifeline100*, *Linkup*, and *Autoenroll* as endogenous is that these policy variables are concerned directly with increasing the telephone penetration of poor households, and therefore are might be correlated with unobservable (or uncontrolled for) characteristics of this population. Even though *Access4* and *Local Calling Area* are also determined by state regulators, we treat these as exogenous on the grounds that these variables determined in regulatory proceedings that are predominantly not related to low-income support programs.

¹⁶ See Riordan (2002) for the empirical significance of weather-related variables in a reduced form specification.

Table 1 provides summary statistics on the variables used in the analysis.

Table 1
Summary Statistics

<u>Variable</u>	<u>Mean</u>	<u>Std. Dev.</u>	<u>Min</u>	<u>Max</u>
<i>Penetration</i>	0.934	0.086	0.257	1
<i>Linkup</i>	10.455	7.666	0	22.950
<i>Lifeline100</i>	7.139	3.164	0.550	15.320
<i>White</i>	0.763	0.257	0	1
<i>Black</i>	0.117	0.220	0	1
<i>Native American</i>	0.016	0.072	0	1
<i>Asians</i>	0.022	0.061	0	0.784
<i>Other</i>	0.084	0.129	0	1
<i>Local Calling Area</i>	212,401	320,866	252	1,810,226
<i>Access4</i>	0.143	0.091	0.026	0.473
<i>Autoenroll</i>	0.272	0.445	0	0.473
<i>RuralPercent</i>	0.270	0.417	0	1
<i>Cost</i>	32.41	20.73	14.63	329.82
<i>Democrat ratio</i>	0.531	0.130	0.114	0.860
<i>Bus-Res Lines</i>	0.502	0.075	0.348	0.662
<i>PUCElect</i>	0.107	0.309	0	1
<i>State Poor</i>	0.122	0.030	0.065	0.199
<i>State Cost</i>	22.36	4.45	18.07	38.96
<i>State Black</i>	0.231	0.147	0.006	0.630
<i>State Native American</i>	0.017	0.035	0.003	0.293
<i>State Asian</i>	0.033	0.026	0.005	0.099
<i>State Other</i>	0.128	0.090	0.015	0.349

Results

The regression equation based on equation (6) above. The relationship that we estimate is of the form:

$$\ln(\textit{Penetration}) = \beta_0 + \beta_1 * [\ln(\textit{Lifeline100} + e^{\beta_2 * \textit{Linkup}})] + \ln[\textit{White} + \beta_3 * \textit{Black} + \beta_4 * \textit{Native American} + \beta_5 * \textit{Asian} + \beta_6 * \textit{Other}] + \beta_7 * \ln(\textit{Local Calling Area}) + \beta_8 * \ln(\textit{Access4}) + \beta_9 * \textit{Autoenroll} + \beta_{10} * \textit{Rural Percent} + \text{Possible Controls for Weather} + \text{Error Term}$$

The regression equation is nonlinear because of the treatment of the amortized Linkup charge and the aggregation of demographic groups. Both sources of non-linearity are suggested by economic theory, as discussed earlier.

We estimate the regression relationships with two alternative GMM estimators. The first estimator treats all right-hand side variables as exogenous. The second estimator treats *Lifeline100*, *Linkup*, and *Autoenroll* as endogenous using the instruments discussed in the previous section. The regression results are presented in Table 2. The first and third columns do not include controls for weather (*Temperature* and *Precipitation*) and the second and fourth columns include weather controls. The reported standard errors are robust standard errors that allow arbitrary clustering of errors at the state level. All variables are measured at the Census “place” level, for which we have 8,120 observations.

The main parameters of interest are β_1 and β_2 . As discussed earlier, the coefficient β_1 estimates the elasticity of the monthly price of Lifeline service, including an estimated amortization of Linkup charge. The coefficient e^{β_2} estimates the amortization rate for the Linkup charge; the exponential form imposes the restriction that the amortization rate is positive. The regression controls for the demographic characteristics of the local population, how rural is the locality, the characteristics of

Lifeline calling plan, including the size of the local calling area, and (in some specifications) intrastate long distance access charges.

The GMM estimator with all right-hand-side variables exogenous shows a price elasticity of demand for poor households of 0.0124 without controls for weather (column 1) and 0.0291 with weather controls (column 2), although only the latter is statistically significant. These estimates of a low elasticity of demand for telephone service are similar to elasticities reported in previous studies like Taylor (1994) and Crandall and Waverman (2000).

The GMM estimates that control for the possible endogeneity of *Lifeline100*, *Linkup*, and *Autoenroll*, present a somewhat different perspective. The estimated price elasticity of monthly Lifeline/Linkup service rises to 0.0574 without weather controls and 0.0529 with weather controls. These estimates are statistically and quantitatively significant. This estimated price elasticity of demand for poor households is still small, but with the weather variables it is roughly double the estimated elasticity when not accounting for potential endogeneity problems. These results suggest that endogeneity of low-income support policies is a potentially important source of bias for estimating the price elasticity of demand of poor households. Accordingly, the rest of our discussion focuses on GMM estimates that control for the possible endogeneity of *Lifeline100*, *Linkup*, and *Autoenroll*.

Table 2
GMM Estimates
Dependent Variable: $\ln(\text{Penetration})$
(Standard errors in parentheses)

	All exogenous		Endogenous <i>Lifeline100</i> , <i>Linkup</i> , and <i>Autoenroll</i>	
β_0	-0.1732*** (0.0339)	0.01356 (0.0579)	-0.0583 (0.0596)	0.0353 (0.0800)
$\beta_1 \cdot [\ln(\text{Lifeline100} + e^{\beta_2} \cdot \text{Linkup})]$	-0.0124 (0.0105)	-0.0299*** (0.0072)	-0.0574*** 0.0213	-0.0529*** (0.0104)
$e^{\beta_2} \cdot \text{Linkup}$	-0.8820 (1.1273)	-3.3216* (1.6221)	-1.1437*** (0.3818)	-2.4404*** (0.9208)
$\beta_3 \cdot \text{Black}$	0.8978*** (0.0092)	0.9178*** (0.0060)	0.8979*** (0.0079)	0.9223*** (0.0073)
$\beta_4 \cdot \text{Native American}$	0.7273*** (0.0228)	0.7359*** (0.0201)	0.7239*** (0.0206)	0.7487*** (0.0251)
$\beta_5 \cdot \text{Asian}$	1.0439*** (0.0238)	1.0430*** (0.0156)	1.0114*** (0.020)	1.0202* (0.0163)
$\beta_6 \cdot \text{Other}$	0.9214*** (0.0142)	0.9343*** (0.0158)	0.9046*** (0.0161)	0.9162*** (0.0161)
$\beta_7 \cdot \ln(\text{Local Calling Area})$	0.0150*** (0.0016)	0.0180*** (0.0013)	0.0150*** (0.0016)	0.0175*** (0.0014)
$\beta_8 \cdot \ln(\text{Access4})$	0.0068* (0.0039)	0.0022 (0.0043)	0.0127*** (0.0036)	0.0044 (0.0031)
$\beta_9 \cdot \text{Autoenroll}$	0.0244*** (0.0050)	0.0127* (0.0077)	0.0434*** (0.0080)	0.0270*** (0.0064)
$\beta_{10} \cdot \text{Rural Percent}$	-0.0214*** (0.0040)	-0.0171*** (0.0039)	-0.0233*** (0.0050)	-0.0199*** (0.0043)
Controls for weather	No	Yes	No	Yes
N	8120	8120	8120	8120
Adj. R-Squared	?	?	?	?

*significant at 90% level **significant at 95% level ***significant at the 99% level

The estimated coefficient on *Linkup* (controlling for endogeneity) ranges between $e^{-1.1437} = 0.319$ without weather controls and $e^{-2.4404} = 0.087$ with weather controls. The standard errors and exponential transformations of the estimated coefficients yield wide confidence intervals for these monthly discount rates that amortize the expense of an initial connection. The corresponding annual discount rates are respectively 2663% and

177%.¹⁷ The latter seems the more plausible point estimate, even though a very high discount rate for poor households is not an unusual finding. Hausman et. al. (1993) that find a discount rate of greater than 100 per cent per year and work in other fields find high discount rates for low-income households for consumer durables (Hausman (1979) and Dubin and McFadden (1984)). A high discount rate means that the demand for telephone service is very responsive to the connection charge. Crandall and Waverman (2000) also find that subscription is sensitive to the connection charges, but, possibly because of the nature of their data and estimation, find inverse relationships between subscription and Linkup programs.

All of the racial variables that are included are highly statistically significant. The coefficient on *White* essentially is picked up in the constant term because of the logarithmic transformation. Therefore, the estimated coefficient on the other groups should be interpreted as the effect demographic composition on telephone penetration relative to an all white population. As expected, Asians have a higher penetration rate than whites while all other groups have a coefficient less than one, indicating lower penetration rates for these groups relative to white households.

The local calling area variable is also positive and significant. This means that the number of people that low-income households can call locally has a positive effect on the subscription decision. Since there is a high correlation between the number of people within a local calling area and the number of people nearby (urban vs. rural), it is not entirely clear why *Rural Percent* receives a negative coefficient.

¹⁷ The transformations from a monthly discount rate to an annual one are as follows: $(1 + 0.319)^{12} - 1 = 26.638$ and $(1 + 0.087)^{12} - 1 = 1.77$.

The *Autoenroll* variable is positive and significant, except in the model that ignores endogeneity and controls for weather. The coefficient on $\ln(\text{Access4})$ is positive in all four regressions for reasons that are unclear, but is not statistically significant when controlling both endogeneity and weather.

Policy Experiment

Using the estimates from the regression equations, it is possible to estimate the impact of the Lifeline and Linkup plans on low-income penetration. We use the elasticity estimates and the prices for non-eligible customers to see how the penetration rates for low-income customers would change if the Lifeline and Linkup programs were discontinued. We do this using our preferred estimation that includes quadratic controls for weather (*Precipitation* and *Temperature*) and uses instruments to control for the possible endogeneity of *Lifeline100*, *Linkup*, and *Autoenroll*. Table 3 shows the result.

Table 3
Predicted Penetration for Low Income Households

(GMM controlling for weather and endogeneity)

With Lifeline and Linkup	93.31%
Without Lifeline and Linkup	88.90%
Combine effect of Lifeline and Linkup [95% confidence interval]	4.41% [2.46%, 6.37%]
Incremental effect of Linkup ⁺ [95% confidence interval]	1.25% [-0.70%, 3.21%]
Incremental effect of Lifeline ⁺ [95% confidence interval]	3.83% [2.60%, 5.07%]

⁺The nonlinear functional form estimated results in the sum of the separate effects being different than the joint effect where Lifeline and Linkup are both in place.

The predicted penetration rates for low-income households with Lifeline and Linkup rates are significantly and substantially higher than the predicted penetration rates

without these reduced rates. The estimated difference in the penetration rates of poor households is 4.41%. Most of this increase is explained by the incremental effect of Lifeline, i.e. if Lifeline were discontinued then penetration is predicted to be 3.83% lower, with a reasonably tight confidence interval. In contrast, we do measure very well the incremental contribution of Linkup to poor telephone penetration; discontinuing Linkup reduces predicted penetration by 1.25% with a wide confidence interval.¹⁸

To get an idea of the magnitudes of the numbers that are concerned here, the annual federal funding for Lifeline and Linkup was about \$530 million in 2000. There are about 12.6 million low-income households in the country as a whole. A 4.9% increase in penetration among low-income households, means that these programs encourage 617,400 more households to subscribe to the telephone network. This works out to a federal cost of \$859 per household per year.¹⁹

Linkup appears to be much more cost effective than Lifeline. Linkup costs less than 5% of the Lifeline program, yet has 30% of the incremental effect on predicted penetration. Our estimates suggest that regulators might get the same effect on penetration with substantially less money by increasing the Linkup program and reducing the Lifeline program. The Universal Service Administrative Company (2003) reports that the Federal government is running at about \$700 million per year on Lifeline and about \$30 million per year on Linkup, so there is room to undertake this policy adjustment.

¹⁸ These predictions ignore possibly offsetting factors (Hausman, Tardiff, and Belinfante, 1993). Federal low income subsidy programs are funded by taxes on interstate revenues. To the extent that such extra charges are also borne by low-income households, their bills would decrease somewhat, offsetting the increase in hookup and monthly charges.

¹⁹ This does not count the cost of state contributions to Lifeline subsidies. States that reduced the charges by \$3.50 per month, in 2000, qualified for \$7.00 per month in federal price reductions for a total of \$10.50.

Conclusions

Using data from 8,120 places, we conclude that low-income subsidy programs have increased low-income telephone penetration by almost 5%. The elasticity of demand for poor households, while still a relatively low at 0.058, nevertheless is higher than previous estimates for all households. This higher estimates are due substantially to bias corrections that account for the possible the endogeneity of Lifeline and Linkup service offerings in different locations due to different implementations by state regulators. Even with a relatively low price elasticity of demand, the magnitude of Lifeline and Linkup programs are sufficient to reduce substantially the effective prices faced by low-income households so that telephone penetration increases significantly as result of these programs.

Because of the high discount rate that low-income households have, the Linkup program has a much higher effect on penetration per dollar spent than the Lifeline program. One possible explanation for this is that low-income households may be credit constrained and even the typical 50% discount for Linkup charges could be a large amount to put up for telephone service if the expected tenure in the residence is low.

The bottom line is that for \$530 million in federal low-income support in 2000, plus substantial additional state support, an additional 630,000 poor households subscribed to the telephone network.

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