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Abstract

This article combines a discrete choice model of demand for residential local telephone access and an optimal price regulation model to estimate the welfare weights that state regulators place on consumers with different incomes and locations. I find no evidence of a bias towards rural consumers on average, but the relative weight on low income consumers in a geographic area can vary as a function of the proportions of rural and poor population and the political characteristics of the regulator. I also measure the welfare consequences of deviating from total consumer surplus maximization and disconnecting prices from costs.

Keywords: Ramsey prices, regulatory bias, welfare analysis, telecommunications, GMM.

JEL classification: L51, L96, D61.

Resumen

Este artículo combina un modelo de elección discreta para la demanda de acceso residencial a la red telefónica local y un modelo de regulación óptima de precios para estimar los pesos que los reguladores estatales asocian al bienestar de consumidores con distintos niveles de renta y localización geográfica. En media, no se encuentra evidencia de un sesgo a favor de los consumidores rurales, pero sí de que el peso asociado al bienestar de los consumidores de renta baja puede variar como una función de las proporciones de población rural y en situación de pobreza, así como de las características políticas del regulador. También mido las consecuencias en el bienestar social de la desviación con respecto al criterio de maximización del bienestar de los consumidores y de desconectar precios y costes.

Palabras claves: Precios de Ramsey, sesgo regulatorio, análisis del bienestar económico, telecomunicaciones, método generalizado de los momentos.

Códigos JEL: L51, L96, D61.

1 Introduction

Residential access to the telephone network is a local service for which demand and cost conditions differ across the geography and the different social groups of the United States. Optimal prices, which maximize total welfare given the constraints on the regulator, would vary as a function of these different market conditions, but the bias of regulators in favor of particular consumer groups can introduce additional price dispersion. This article estimates the relative welfare weights that state regulators place on the surplus of consumers with different incomes and geographic locations and obtains a measure of the welfare effects of bias towards different consumer groups.

A state telephone regulator in the United States has jurisdiction over multiple local markets and, in principle, it could set a different price for each local market and consumer group. In practice, the pricing policies of state regulators are homogenous across large areas of their jurisdictions. In addition, non-geographic price discrimination is limited to discounted prices for low income consumers. I use an optimal regulation model to rationalize these observed pricing decisions and allow for a regulator's objective function that is a weighted sum of the profits of the firm and consumer surplus. This formal model can accommodate both the cases of a welfare maximizing regulator that acts in the public interest, and a regulator guided by private interest that places different weights across members of its jurisdiction.

Cross subsidies across telecommunications consumers (business to residential, urban to rural, high-income to low-income) have concerned both academics and practitioners.[1] This concern originates from the impact of cross subsidies on profits, and their potential to decrease social welfare by disconnecting prices and costs. A particular form of cross subsidy that lacks rigorous analysis is the possible transfer between urban and rural customers, as pointed out in Riordan (2002). Observation of tariffs for different geographic areas as in Riordan (2002) or Rosston and Wimmer (2005) reveals that telephone rates for rural areas are on average below average cost

[1] The term cross subsidy generally refers to price distortions originated by allowing losses for a subset of services A sustained by positive profits in subset B. Faulhaber (1975) provides a formal definition characterizing a price structure as subsidy-free if revenues do not exceed stand-alone costs for any subset of services. Palmer (1992) finds positive evidence of a subsidy from business to residential telephone users.

and lower than in corresponding urban areas. This observation alone is not enough to conclude that there is a different weight on urban and rural consumers as demand and marginal costs also differ across these areas. For example, the higher cost of service in a rural area is not incorporated fully in the optimal price if demand for telephone service is weaker than in urban areas. The formal regulation model and GMM estimation methods allow me to separate demand and cost factors from regulatory bias.

I estimate the demand for telephone access with a discrete choice model applied to a broad cross section of local market data in the US. I combine simulation techniques and the empirical income distribution in the Census of the United States to control for household heterogeneity in income and participation in welfare programs. Income affects the price sensitivity of a household, but also the actual price schedule of the household through the presence of low income subsidies. The estimated average demand elasticity is low, although low income households, who are potential marginal adopters, exhibit significantly higher average elasticity.

The relative welfare weights of consumers are estimated under different assumptions on the cost of service. Engineering cost data from the Federal Communications Commission (FCC) is used to estimate the average and marginal costs per line used in the welfare maximization problem of the regulator. I also consider different assumptions on the fraction of the cost of subsidy programs that is internalized by state regulators. The federal government funds part of the price subsidies to low income customers and high cost areas. If the federal portion of the cost of price subsidies is not internalized by a state regulator, it might reduce prices for the subsidized consumers even if it does not put a high weight on their welfare.

I find some evidence in favor of the existence of differences in welfare weights across consumers, and that these differences are connected to the percentage of rural and poor population in an area. For the different specifications, a higher percentage of rural population in a geographic area is seen to increase the weight in favor of the low income consumers in that area. On the contrary, the estimated weights on consumers that are not low income do not increase significantly in rural areas.

The effect of the percentage of poor population depends on the specification considered. If the cost of federal funding is internalized by state regulators, I find a high relative weight on low income consumers in geographic areas with a high percentage of poor population. This result is reversed if I assume that the costs of federal subsidy programs are not internalized by state regulators. The exclusion of the federal portion reduces significantly the cost of low income subsidies. Under this assumption, the fact that state regulators are not allowing a higher level of subsidies implies then a low weight on the welfare of low income consumers. Political controls also turn significant in this latter specification, with the percentage of democrats in the regulatory body and direct election associated to higher weights on low income consumers.

Counterfactual experiments examine first the alignment of prices with estimated marginal and average costs. Actual residential telephone prices are generally below marginal line costs, and the resulting deficit is covered by the profits of the firm in other sectors and regulatory subsidies. The change from actual to cost oriented prices leads to a substantial transfer from consumers to firms ($8.5bn annually for marginal cost pricing). However, the adjustment in total welfare is moderate ($192m annually for marginal cost pricing). Unless indirect efficiency gains are sizeable, the reduction in consumer surplus from the shift to cost oriented prices well exceeds the increase in total welfare.

I also study the shift to prices maximizing unweighted consumer surplus given a constant deficit. This policy eliminates the bias across consumers and it produces a transfer from low income consumers to the general population. Finally, I examine prices maximizing total welfare with the constraint of recovering the total cost of residential telephone service. The results of this experiment are close to the cost oriented pricing rules with reductions in low income telephone penetration, substantial redistribution from consumers to firms and moderate increases in total welfare. The welfare gains in this set of experiments increase only moderately if full price discrimination across local markets is allowed. This provides some support for the broad geographic price zones used by state regulators.

The demand for telephone access across the United States has been studied with aggregate data in a number of works including Taylor and Kreidel (1990), Hausman et al. (1993), Crandall and Waverman (2000), Ross et al. (1998), Garbacz and Thompson (2002) and Ackerberg et al. (2008). An important motivation of these studies is measuring the elasticity of demand for local telephone access to prices in order to evaluate the effect of federal and state subsidies. Hausman et al. (1993) use Federal Communications Commission (FCC) data on penetration aggregated over multiple local markets and conclude that there is a low elasticity of access to price. Ross et al. (1998) and Garbacz and Thompson (2002) find similar results with the use of state-wide data. For example, Garbacz and Thompson (2002) find own price elasticity in the range of -0.006 and -0.011, a value close to the -0.005 in Hausman et al. (1993). The use of aggregated data masks variation in local conditions and the aggregation of all consumers masks the possible differences in demand elasticity of different demographic groups. Ackerberg et al. (2008) address these shortcomings with a sample at the local market level focused on poor households, who are more likely to have an homogenous price elasticity. Ackerberg et al. (2008) also control for the endogeneity of prices and subsidies. The current article contributes to this literature considering how to control with aggregate data and simulation methods for the differences in marginal utility of income across demographic groups and introducing an explicit optimal regulation model for the endogenous choice of prices.[2]

The use of discrete choice models with simulation to study markets for differentiated goods and heterogenous consumers has become popular in the empirical IO literature following the work of Berry, Levinsohn and Pakes (1995), BLP henceforth. This estimation framework is well known, with clear asymptotic properties of the estimator set in Berry, Linton and Pakes (2004). Applications are numerous, including examples such as Nevo (2000, 2001) and Ho (2006).

A related strand of the literature studies demand for telephone services with micro data in articles such as Perl (1984), Train et al. (1987), Miravete (2002), Wolak (1996), and Economides et al. (2008). This micro data allows to control directly for the effect of individual income and demographic characteristics. Additionally, the observation of individual usage and choices over price menus allows one to estimate not only the demand for access but also for the number of

[2]The pioneering study by Taylor and Kreidel (1990) considered the aggregation of individual demand functions for telephone access according to the distribution of income. Taylor (1994) Chapter 5.II reproduces this work. The estimator used in this study does not allow to derive standard errors for the price coefficients, see p. 103 of Taylor (1994).

calls, duration and service plans. These articles find a low average elasticity of local usage to the price per call and that households make a stable number of local calls per month. These findings provide some justification for the use of the minimum cost of a fixed number of monthly calls as a proxy for the cost of local telephone service in the studies with aggregate data.

The study of telecommunications regulation includes examples such as Ai and Sappington (2002), Ai, Martinez and Sappington (2004), Donald and Sappington (1995) and Greenstein, McMaster and Spiller (1995), Rosston and Wimmer (2005) and Rosston et al. (2008). These empirical studies estimate the effect of different economic and political characteristics of the state on the choices of regulators (price and quality levels, incentive plans, etc.) and the firm (investment, etc.). This literature connects with the early work of Joskow (1972, 1973) that studies the interaction between regulatory process and policy for regulated utilities. The present work is closest to Rosston et al. (2008) as that article studies the effect of private interest groups on the structure of telephone prices (retail, business and wholesale) by estimating a system of price equations that controls for demand, cost and political factors. The current article is focused on residential prices and it contributes to this literature with a structural approach that recovers information on the objective function of the regulator and welfare variations.

Related structural studies of regulation include Wolak (1994), Gagnepain and Ivaldi (2002) and Timmins (2002). Wolak (1994) estimates the production function of regulated water utilities and tests for the presence of private cost information. Gagnepain and Ivaldi (2002) also focus on the estimation of the production function and private information of the firm.[3] Gagnepain and Ivaldi (2002) do not use the assumption of an optimizing regulator for estimation but they use the optimal regulation model to calculate counterfactual welfare levels of alternative regulation regimes. Timmins (2002) recovers the forward-looking costs of water supply in California and he uses a regulator's welfare function with weight differences only between consumers and the firm. I allow the weights on different consumer groups to vary as a function of their demographic and political characteristics.

[3] Seminal models of industrial regulation with asymmetric information include Baron and Myerson (1982) and Laffont and Tirole (1986). See Vuong and Perrigne (2004) estimation methodology for Laffont and Tirole (1986).

The use of an optimal regulation model to separate welfare weights can be traced back to Ross (1984). This article spanned a series of empirical applications such as Morrison (1987), Kim (1995) and Knittel (2003). I contribute to this literature with the joint GMM estimation of the demand and the structural regulation models.

The rest of the article is organized as follows. Section 2 provides basic background on the local telephone sector. Section 3 provides a description of the data set. Section 4 presents the demand and regulation models. Section 5 builds the estimation procedure. Section 6 presents results. Section 7 introduces policy experiments. Section 8 concludes.

2 Local Telephone Network in the US

A local telephone network combines a wire center (or switching office) and connection facilities (lines), which are operated by a local carrier firm. Gasmi et al. (2002) provide a detailed technical description of local telephone networks. Local telephone markets in the United States have been typically served by a single firm denominated as local exchange carrier (LEC) and subject to price and quality regulation. A single firm, AT&T, dominated the majority of local markets and the long distance segment for most of the past century.

The presence of fixed cost elements in the local network can create returns of scale and scope that make the duplication of the infrastructure socially undesirable.[4] Price regulation is then justified as a mean to sustain adequate investment in infrastructure and, at the same time, limit the exercise of monopoly power. A regulator could also be more capable of ensuring generalized access to the Telecommunication network, a goal that can be termed as Universal Service. Alternatively, a market solution can provide better incentives for allocative (lower demand distortions) and dynamic (investment) efficiency. The FCC, courts and legislators progressively moved from the regulatory to the market paradigm over the second half of the last century. The regulatory reform process culminated into the Telecommunications Act of 1996. Brock (2002), Hausman (2002) and Woroch (2002) provide a complete historical overview.

[4]To test for the presence of returns to scale and scope, Evans and Heckman (1983) and Shin and Ying (1992) use historical AT&T data, whereas Gabel and Kennet (1994) and Gasmi, Laffont and Sharkey (1997) use data from engineering cost simulations and find stronger evidence in favor of returns of scale and scope than the earlier articles.

The Telecommunications Act of 1996, TA of 1996 henceforth, aimed to provide a legal framework that facilitated competition in all the segments of the industry. New competitive local exchange carriers (CLECs) would enter local telephone markets and compete with the incumbent local carriers (ILECs). The TA of 1996 did not however eliminate the regulatory powers of the states and the FCC. The power of state regulators over tariffs is backed by the US Supreme Court jurisprudence.[5] State regulators maintained their authority over local retail prices and they were assigned the task to mediate between ILECs and CLECs in the pricing of wholesale access. The FCC initially favored a forward looking cost methodology to determine wholesale prices, but litigation by the ILECs lead to the adoption of the Review Remand Order (2004) with an upward revision of access prices.

Data from Kaserman and Mayo (2002) and Woroch (2002) reveals that, in year 2000, the vast majority of the local network (approximately 94% of total local area revenues totalling $111.8bn at 1999 year end) was operated by incumbent local companies, either independent or part of Regional Bell Operating Companies (RBOCs) with presence in several states. Additionally, CLECs focus on business users and have a small presence in the residential sector. Economides et al. (2008) also reveal that the entry of competition in local residential telephony does not lead to big changes in the average price level. The preferred formal process of regulation of state tariffs in year 2000 was price cap, as documented in Ai and Sappington (2002). Price caps below the monopoly price will be a binding constraint for regulated ILECs that face moderate competition.

The TA of 1996 also created explicit universal service subsidies targeted to schools, rural health providers, low income users and high cost areas.[6] State regulators influence the implementation of universal service subsidies through the designation of eligible carriers to different

[5] *Federal Power Commission v. Hope Natural Gas (Hope) in 320 U.S. 591 (1944)* and *Bluefield Water Works & Improvement Co. v. Public Service Commission of West Virginia in 262 U.S. 679 (1923).* Gifford (2003) provides a brief overview of the legal framework.

[6] The Universal Service Administrative Company (USAC) is an agency created by the FCC to administer the Universal Service Fund. From 1998 to 2008, the Fund has disbursed approximately $ 57.7bn in different programs. See http://www.usac.org/default.aspx for a detailed breakdown.

programs, and choice of price subsidies to low income users. There are currently two programs that reduce the cost of telephone access to low income users: the Lifeline program, which reduces monthly charges, and the Linkup program, which reduces connection charges. I describe these programs in more detail below.

Current policy debate is concerned with the further regulation of the Internet and improvement of Universal Service with a possible extension of subsidies to Broadband Internet. The Communications Opportunity, Promotion and Enhancement (COPE) Act of 2006 contains specific developments in this area. The experience in the regulation of the local telephone network can provide a guideline for the extension of Internet regulation.

3 Data Set

Data on local market characteristics (race groups, income distribution, network size, etc.), state regulators (tariffs, political composition, election rule, etc.) and the costs of the firm are drawn from the United States Census (2000) and reports of the FCC and state regulators. I obtained most of this information from the data set in Ackerberg et al. (2008).[7] The data set covers 7,118 wire center locations in 43 states and the District of Columbia for the original RBOC regions in the year 2000.

I use the wire center as definition of local market based on the geographic proximity of the households and the homogenous cost of service inside these areas. The variation in demand and operational conditions across wire centers contains information that might be masked at the state level, e. g., dispersion in penetration levels across the state.

The United States Census (2000) is the source of demand information and it allows me to construct the percentage of total households in a wire center with telephone service, *Tel Pen Total*. The definitions of local market demographic variables are relegated to the Appendix A. Panel (a) of Table 1 provides summary statistics for these demographic variables. Sections 3.1 and 3.2 describe the price and cost data.

[7] I indicate clearly below the additional information that I add to the original data set in Ackerberg et al. (2008).

3.1 Prices and Low-Income Discounts

The information on regulated tariffs in year 2000 was collected directly from the public utility commissions for Ackerberg et al. (2008). The local telephone service is charged according to usage-based, flat or hybrid rate plans. This raw tariff data was used to construct the minimum expense of completing different numbers of local calls per month: no calls (the utility of the telephone line is limited to completing emergency calls), 50, 100 and 200 calls. The different proxies for the cost of telephone access are then labeled: $Monthly\_0$, $Monthly\_50$, $Monthly\_100$ and $Monthly\_200$. The differences between these price variables are moderated through the presence of flat rate components in the different tariff plans. The use of price proxies is imposed by the absence of detailed usage data, but it is reasonable given that previous literature found that local calls are not sensitive to usage prices and the prevalence of flat tariffs. I will focus on $Monthly\_50$, a price proxy consistent with moderate use of the service that is also employed in Ackerberg et al. (2008). The initial installation charge, $Connection$, is included as an additional price control.

Low income consumers can access lower rates through participation in the Lifeline and Linkup programs. The Lifeline program subsidizes the monthly cost of telephone service and the Linkup program reduces the initial connection charge. The basic levels of both programs are covered with federal funds, but state regulators are free to set additional subsidies. In the case of the Lifeline program, additional federal contributions will match every dollar of state subsidies with 50 cents up to a discount cap. The corresponding proxies for subsidized prices are listed as $Monthly\_0(sub)$, $Monthly\_50(sub)$, $Monthly\_100(sub)$, $Monthly\_200(sub)$ and $Connection(sub)$. Additional details on the political profile of regulators, competition and the price setting process are relegated to the Appendix A. Panel (b) of Table 1 provides summary statistics of state public utility commissions (PUCs), competition and prices.

3.2 Cost and Quality Characteristics

The cost data is drawn from the Hybrid Cost Proxy Model (HCPM) used by the FCC to determine which wire centers are above the national average cost of service. The FCC Ninth Report and Order (1999) set subsidies for non rural ILECs in states with average costs above the HCPM national cost benchmark. This FCC Order also set transitional hold-harmless subsidies for non rural ILECs that did not qualify under the HCPM criteria but received subsidies under preexisting programs. All companies in the sample qualify as non rural.

I form with the HCPM data estimates of average and marginal cost per line in year 2000. For a target number of users, the HCPM uses the geographic characteristics of wire centers and input prices to calculate the minimum total cost of building and operating the local network. The HCPM also provides an estimate of the cost of capital of regulated ILECs: 11.25%. This figure is based on the target returns for the price cap programs of the FCC in the 1990s. I use the evolution of corporate bond rates to proxy for the change in the cost of capital and obtain an updated estimate of 8.75 %.[8] Appendix A provides additional details on the implementation of the HCPM. Panel (c) of Table 1 provides summary statistics for the HCPM average cost.

4 Model

I will henceforth use the term local market rather than wire center. In Section 4.1, I set up the demand model. The reader exclusively interested in demand can read this subsection and skip ahead to estimation and results in 5.1, 6.1 and 6.2. Section 4.2 sets up the maximization problem of the regulator. Sections 4.3 and 4.4 form the first order conditions derived from the optimization problem in 4.2. Section 5.2. ahead adapts the first order conditions to the estimation procedure. The derivations are presented for a given state s so I save the inclusion of subindex s in functions to lighten notation. I summarize the notation employed throughout sections 4 and 5 in Table 2.

[8] The original computation assumes 44% of debt in the capital structure, a cost of debt of 8.8% and cost of equity of 13.2%. The evolution of Moody's Baa Corporate Bonds is used to measure the decrease in the cost of equity from 1991 to 2000. See pp. 74-76 in Uri (2004) for a more detailed review of the argument.

4.1 Demand for Residential Telephone Access

I derive the local market demand function by applying a random utility model to the local market level. A state s is divided into Z_s price zones and each price zone contains N_{zs} local markets. A household i in local market $j \in \{1, ..., N_{zs}\}$ at a price zone $z \in \{1, ...Z_s\}$ obtains random utility u_{ijz} from access to the local telephone network. Formally,

$$u_{ijz} = x_{jz}\beta - \widetilde{p}_{zi} \cdot \alpha_i + \xi_{jz} + \epsilon_{ijz} \tag{1}$$

where x_{jz} is a $(1 \times X_1)$ vector of observed local market characteristics affecting the mean value of service (for example, ethnic composition and number of households in the local calling area). Net Prices are listed in the (1×2) vector $\widetilde{p}_{zi} \equiv [\widetilde{p}_{zi}(m),\ \widetilde{p}_{zi}(c)]$, where $\widetilde{p}_{zi}(m)$ is the net monthly fee and $\widetilde{p}_{zi}(c)$ is the net connection charge faced by household i.[9] The subindex i indicates that discounts are a function of the income of household i.

The price coefficients are in a (2×1) vector $\alpha_i \equiv\ [\alpha_i(m),\ \alpha_i(c)]^T$, where $\alpha_i(m)$ equals the household i marginal utility of income (MUI) and $\alpha_i(c)$ equals the marginal utility from a connection charge reduction. The connection charge is a one time payment for household i and the equivalent monthly perpetual payment equals $\widetilde{p}_{zi}(c) \cdot r_i$, where r_i is the discount rate of the household. The disutility from the payment $\widetilde{p}_{zi}(c)$ still depends on the marginal utility of income $\alpha_i(m)$, so $\alpha_i(c) = r_i \cdot \alpha_i(m)$. I assume $\alpha_i(m)$ to be inversely proportional to household income I_i leading to the specification:[10]

$$\alpha_i = [\alpha(m)/I_i,\ \alpha(c)/I_i]^T$$

where $\alpha \equiv\ [\alpha(m),\ \alpha(c)]^T$ are constants. The unobserved elements of utility include the mean market quality ξ_{jz} (unobserved to the econometrician but available to the rest of agents) and a purely idiosyncratic shock ϵ_{ijz} with the standard Type-I (Gumbell) extreme value distribution.

[9] Net prices $\widetilde{p}_{zi}$ are calculated as the difference of regular prices p_z and discounts d_{zi} for low income consumers: $\widetilde{p}_{zi}\ = p_z - d_{zi}$. Note that $p_z \equiv [p_z(m),\ p_z(c)]$ and $d_{zi} \equiv [d_{zi}(m),\ d_{zi}(c)]$. The term $\widetilde{p}_z$ denotes the set of all net prices in zone z.

[10] This formulation is a linear approximation to the disutility of price in the logarithmic term $[\log(I_i - p_{zi}(m) - r \cdot p_{zi}(z)) - \log(I_i)] \cdot \alpha$ derived from a Cobb-Douglas utility function in BLP (1995) and assuming the same discount for all households. I lack data to allow varying discounts r .

The distribution of ξ_{jz} is left unspecified. The telephone adoption choice of a household depends only on the difference between u_{ijz} and the utility of the best outside option u_{ijz0}. The mean utility of the outside option, $x_{jz0}\beta_0+\xi_{jz0}$, is normalized to zero, as it is standard in the literature, and u_{ijz0} is subject to the shock ϵ_{ijz0} with the logit form. The distributional assumptions on ϵ_{ijz}, ϵ_{ijz0} allow me to derive an analytic expression for the probability of telephone adoption of household i at location jz:

$$P_{ijz}(x_{jz}, \widetilde{p}_{zi}, \xi_{jz}, I_i, \Theta_D) = \frac{\exp(x_{jz}\beta - \widetilde{p}_{zi} \cdot \alpha_i + \xi_{jz})}{1 + \exp(x_{jz}\beta - \widetilde{p}_{zi} \cdot \alpha_i + \xi_{jz})} \tag{2}$$

where Θ_D condenses the demand side parameters. The expectation of P_{ijz} with respect to household income I_i (both α_i and $\widetilde{p}_{zi}$ are a function of income) yields the proportion of households P_{jz} with local telephone service at location jz. That is,

$$P_{jz}(x_{jz}, \widetilde{p}_z, \xi_{jz}, \Theta_D) = \int_{A(I),\ A(\epsilon)} P_{ijz}(x_{jz}, \widetilde{p}_{zi}, \xi_{jz}, I_i, \Theta_D) dF_{jz} \tag{3}$$

Income and idiosyncratic shocks have the distribution functions $F_{jz}(I)$ and $F(\epsilon)$, with density functions $f_{jz}(I)$ and $f(\epsilon)$ and support in $A(I)$ and $A(\epsilon)$. The integration term dF_{jz} is:

$$dF_{jz} = f_{jz}(I) \cdot f(\epsilon) \cdot dI \cdot d\epsilon$$

The demand D_{jz} in market j in zone z is simply the product of P_{jz} and the number of households M_{jz}. I also use the probability of adoption P_{jzg} and the demand D_{jzg} of a specific demographic group g by drawing households exclusively from the distribution of this group, i. e. $F_{jz}(I, \epsilon | i \in g)$.[11] In particular, I can compute the probability of adoption of households divided in G income levels.

[11] For example, the demand D_{jz} at location jz with a group 1 and a group 2 can be equivalently recovered as $P_{jz} \cdot M_{jz} = D_{jz}$ or $P_{jz1} \cdot M_{jz1} + P_{jz2} \cdot M_{jz2} = (P_{jz1} \cdot \Pr_{jz}(i \in 1) + P_{jz2} \cdot \Pr_{jz}(i \in 2)) \cdot M_{jz} = P_{jz} \cdot M_{jz} = D_{jz}$. Here, $\Pr_{jz}(i \in g)$ denotes the proportion of the population belonging to group g.

4.2 The Regulator

I consider a set of state regulators $s \in \{1,...S\}$ with jurisdiction over multiple local markets distributed across a set of price zones $\{1,...Z_s\}$ for each state s. The set of price zones is taken as an exogenous constraint for regulator s. The redefinition of the price zones would require a different regulatory procedure and higher administrative costs. The policy experiments in Section 7.2 reveal that the welfare costs of the zone pricing restrictions are small, indicating that the local markets in a zone are homogeneous. If regulators are informed of this fact, they will be reluctant to redefine the price zones for a moderate welfare gain.

In each price zone $z \in \{1,...Z_s\}$, the regulator chooses a net residential monthly price $\widetilde{p}_{zg}(m)$ for each of the different groups of residential users $g \in \{1,...,G\}$. The term $\widetilde{p}_{zg}$ is (1×2) vector that combines $\widetilde{p}_{zg}(m)$ and net connection price $\widetilde{p}_{zg}(c)$ for a group g. The full set of net prices in a zone z is denoted as $\widetilde{p}_z \equiv \{\widetilde{p}_{z1},...,\widetilde{p}_{zg},...,\widetilde{p}_{zG}\}$.

I focus on the decision over the monthly charge $\widetilde{p}_{zg}(m)$, which constitutes the main expense associated to local phone service for consumers. The connection charge $\widetilde{p}_{zg}(c)$ is assumed exogenous, as it is set at the state level and represents a small fraction of residential telephone revenues. The results in Ackerberg et al. (2008) and the tests in the Appendix E also provide empirical evidence of the exogeneity of $\widetilde{p}_{zg}(c)$ with respect to unobserved local demand conditions. I assume an objective function W_s for regulator s that captures the trade-off between consumer surplus and profits in the choice of $\widetilde{p}_{zg}(m)$. That is,

$$W_s = E\left[\sum_{z=1}^{Z_s}\left(\sum_{j=1}^{N_{zs}}\sum_{g=1}^{G}\lambda_{zg}\cdot CS_{jzg}(\widetilde{p}_{zg},.)+\pi_{jzg}(\widetilde{p}_{zg},.)\right)\mid \iota_s\right] \tag{4}$$

where π_{jzg} and CS_{jzg} are the profit of the firm and consumer surplus from residential local telephone use of group g in local market jz. The term λ_{zg} is the welfare weight of the regulator on consumers of group g (with respect to the firm) in price zone z. The objective function of the regulator is the expected weighted welfare $E[\ .\ \mid \iota_s]$ given its information set ι_s.

I adapt the general model to the regime of subsidies implemented through the Lifeline and Linkup programs. I set the number of groups to $G = 2$ for a subsidy eligible (low income) consumer group and a non-eligible consumer group. Given this degree of flexibility for regulatory pricing, the variation of prices across zones or customer types might respond to different demand and cost conditions across groups and zones, or dispersion in the λ_{zg} weights.

A regulator with bias is still constrained by the need of the firm to break even at the state level. The recovery of a minimum revenue base from the regulated local telephone activity might be required by state statutes and, even if this requirement is lax, the regulator is constrained by the possibility of bankruptcy. The profit constraint of the regulator is then given by:

$$E\left[\sum_{z=1}^{Z_s}\sum_{j=1}^{N_{zs}}\sum_{g=1}^{2}\pi_{jzg}(\widetilde{p}_{zg},.) - B_s \mid \iota_s\right] \geq 0 \tag{5}$$

where B_s is the required profit from local residential phone service in state s. The term B_s reasonably increases in the level of debt of the regulated company and it decreases with the size of the profits from other services offered (business local telephone service, etc.) and profits from other states in which the firm operates. I do not specify B_s, as it is no part of the welfare changes induced by the price variations used in Section (5.2) to identify the welfare weights.

Consumer Surplus

The expected total consumer surplus is derived as the product of the total number of households and the expectation of household surplus with respect to the household income and idiosyncratic shocks. The mean market value at every local market jz, $\delta_{jz} = x_{jz}\beta + \xi_{jz}$, forms part of the information set of the regulator. This is reasonable given that local telephone is a mature sector where regulators are likely to have good information about mean local market conditions but they lack detailed micro data. Formally, consumer surplus at location j in zone z for group g is given by:

$$E\left[CS_{jzg}(x_{jz}, \widetilde{p}_z, \xi_{jz}, \Theta_D) \mid \iota_s\right] = M_{jzg} \cdot \int_{A(I)} \frac{1}{\alpha_i(m)} \int_{A(\epsilon)} (x_{jz}\beta - \widetilde{p}_{zg} \cdot \alpha_i + \xi_{jz} + \epsilon_{ijz})\, dF_{jzg}$$

where M_{jzg} denotes the number of households in a group g at location j in zone z and division by the MUI, $\alpha_i(m)$, reduces the consumer surplus to monetary units comparable with the profit of the firm. The notation in equation (4) is expanded here to account for dependence on all demand variables and parameters. The term dF_{jzg} incorporates the density with respect to income and the idiosyncractic shock for group g. That is,

$$dF_{jzg} = f_{jzg}(I) \cdot f(\epsilon) \cdot dI \cdot d\epsilon$$

The logit form of ϵ_{ijz} also allows to write the above formula for consumer surplus more explicitly as:

$$E\left[CS_{jzg}(x_{jz}, \widetilde{p}_{zg}, \xi_{jz}, \Theta_D) \mid \iota_s\right] = M_{jzg} \cdot \int_{A(I)} \frac{Ln\ \left(1 + \exp(x_{jz}\beta - \widetilde{p}_{zg} \cdot \alpha_i + \xi_{jz})\right)}{\alpha_i(m)}\ f_{jzg}(I)dI$$

Given $G = 2$ consumer groups and N_{zs} local markets inside a price zone, the total consumer surplus evaluated by the regulator is:

$$\sum_{z=1}^{Z_s}\sum_{j=1}^{N_{zs}}\sum_{g=1}^{2} \lambda_{zg} \cdot E\left[CS_{jzg}(\widetilde{p}_{zg},\ .) \mid \iota_s\right]$$

where notation for all arguments except net prices $\widetilde{p}_{zg}$ has been omitted.

Profit

The regulator's expectation of the profit of the firm in local market jz for each group g depends on the expected demand function D_{jzg}, net monthly price $\widetilde{p}_{zg}(m)$ and net connection charge $\widetilde{p}_{zg}(c)$, the monthly discount of the firm r_s, expected marginal monthly cost per line mc_{jz} and expected fixed cost K_{jz}. The connection charge $\widetilde{p}_{zg}(c)$ is a one time revenue and I use the cost of capital in the HCPM (8.75%) to proxy for the discount rate r_s and compute a monthly payment comparable to the monthly fee $\widetilde{p}_{zg}(m)$.[12] The knowledge of mean value δ_{jz} allows the regulator to calculate the expected rate of adoption P_{jzg} as in (3) and expected demand $D_{jzg} = M_{jzg} \cdot P_{jzg}$.

[12] The adjusted monthly connection charge is simply given by $\widetilde{p}_{zg}(c) \cdot r_s$. This form of firm revenues neglects the fact that $\widetilde{p}_{zg}(c)$ represents a sunk cost for a majority of consumers but it is a good aproximation as long as regulated monthly prices are not set high enough that a substantial fraction of the installed base decides to drop local telephone service.

The profit function and the first order conditions with respect to prices in sections 4.3 and 4.4 are assumed to be linear in cost terms. It is then possible to integrate with respect to the distribution of cost and input the regulator's best estimate for cost terms $E[mc_{jz} \mid \iota_s]$ and $E[K_{jz} \mid \iota_s]$ in these expressions. I then write expected monthly profits at jz from group g as:

$$E[\pi_{jzg}(\widetilde{p}_{zg}, .) \mid \iota_s] = (\widetilde{p}_{zg}(m) + \widetilde{p}_{zg}(c) \cdot r_s - E[mc_{jz} \mid \iota_s]) \cdot D_{jzg} - (1/G) \cdot E[K_{jz} \mid \iota_s] \qquad (6)$$

The profit of the firm operating in state s results from the sum of revenues and costs across the different price zones $\{1, 2, ..., Z_s\}$ and the local markets inside each zone:

$$E[\pi_s(\widetilde{p}_1, ..., \widetilde{p}_z, ..., \widetilde{p}_{Z_s}) \mid \iota_s] = \sum_{z=1}^{Z_s} \sum_{j=1}^{N_{zs}} \sum_{g=1}^{2} E[\pi_{jzg}(\widetilde{p}_{zg}, .) \mid \iota_s]$$

The use of net prices $\widetilde{p}_{zg}$ in (6) assumes full internalization of the cost of price discount programs by state regulators. However, the discounts are not entirely funded from state sources but also disbursements from the federal Universal Service Fund (USF). State regulators might still weigh the costs of USF funds if higher future contributions to USF, or increased administrative costs, are associated to a greater current use of the USF. I formulate in the next subsection a model with partial internalization of subsidy costs and I estimate both models.

The regulator's best estimate of marginal cost is assumed linear in a set cost shifters $E[mc_{jz} \mid \iota_s] = \gamma \cdot Cost_{jz}$. This is formally equivalent to the marginal cost being linear in the vector of cost shifters $Cost_{jz}$ and a mean independent shock ω_{jz}:

$$mc_{jz} = \gamma \cdot Cost_{jz} + \omega_{jz} \qquad (7)$$

It is possible to impose analogous structure into $E[K_{jz} \mid \iota_s]$, but this will not affect the estimation procedure based on the marginal variation in the number of lines.

Regulatory Bias

The weight λ_{zg} that the regulator places in the consumer surplus of group g in zone z is assumed to depend on the political characteristics of the regulator (direct election, party affiliation, etc.) and demographic characteristics of the constituency inside the price zone z. This set of variables is summarized as Pol_{zg}. As an example, the availability of affordable telephone service in rural areas might a priori yield higher political benefits and regulators will put more weight on the consumer surplus in these areas. The following functional form is adopted:

$$\log\left(\lambda_{zg}\right) = \phi \cdot Pol_{zg} + \eta_{zg} \tag{8}$$

where ϕ is a vector of parameters and η_{zg} is a mean independent shock. I denote the parameters (ϕ, γ) jointly as Θ_s capturing the impact of cost and policy shifters. The regulator knows its own preferences so λ_{zg} rather than $E\left[\lambda_{zg} \mid \iota_s\right]$ is used to compute W_s.

4.3 Local Tariff Choice

Given the assumptions in the model, the choice of the net monthly fee $\widetilde{p}_{zg}(m)$ for each price zone z and group g satisfies the following first order condition:

$$\frac{\partial W_s}{\partial \widetilde{p}_{zg}(m)} = E\left[\sum_{j=1}^{N_{zs}} \frac{\partial CS_{jzg}(.)}{\partial \widetilde{p}_{zg}(m)} \cdot \frac{\lambda_{zg}}{1+\mu_s} + \sum_{j=1}^{N_{zs}} \frac{\partial \pi_{jzg}(.)}{\partial \widetilde{p}_{zg}(m)} \mid \iota_s\right] = 0$$

where μ_s denotes the Lagrangian multiplier on the budget constraint restriction at the state level in equation (5). A more useful representation of the problem given $G = 2$ considers the choice for each zone z of a general price $p_z(m)$ and a discount for the low income group $d_z(m)$. The net monthly prices satisfy $\widetilde{p}_{z1}(m) = p_z(m)$ and $\widetilde{p}_{z2}(m) = p_z(m) - d_z(m)$, where $g = 2$ is the low income group. The first order conditions in each zone z are now:

$$\frac{\partial W_s}{\partial p_z(m)} = E\left[\sum_{j=1}^{N_{zs}} \sum_{g=1}^{2} \left(\frac{\partial CS_{jzg}(.)}{\partial p_z(m)} \cdot \frac{\lambda_{zg}}{1+\mu_s} + \frac{\partial \pi_{jzg}(.)}{\partial p_z(m)}\right) \mid \iota_s\right] = 0 \tag{9}$$

$$\frac{\partial W_s}{\partial d_z(m)} = E\left[\sum_{j=1}^{N_{zs}} \frac{\partial CS_{jz2}(.)}{\partial d_z(m)} \cdot \frac{\lambda_{z2}}{1+\mu_s} + \frac{\partial \pi_{jz2}(.)}{\partial d_z(m)} \mid \iota_s\right] = 0 \tag{10}$$

I will use equations (9) and (10) as reference for the estimation section below. It is immediate to rewrite these first order conditions as a function of demand and cost factors expected by the regulator according to the information in ι_s. The expansion of (9) and (10) with the best estimate of costs based in (7) would yield:

$$\sum_{j=1}^{N_{zs}} \sum_{g=1}^{2} \left[-D_{jzg} \cdot \frac{\lambda_{zg}}{1+\mu_s} + D_{jzg} + \frac{\partial D_{jzg}}{\partial p_z(m)} \cdot (\widetilde{p}_{zg}(m) + \widetilde{p}_{zg}(c) \cdot r_s - \gamma \cdot Cost_{jz})\right] = 0 \tag{11}$$

$$\sum_{j=1}^{N_{zs}} \left[D_{jz2} \cdot \frac{\lambda_{z2}}{1+\mu_s} - D_{jz2} + \frac{\partial D_{jz2}}{\partial d_z(m)} \cdot (\widetilde{p}_{z2}(m) + \widetilde{p}_{z2}(c) \cdot r_s - \gamma \cdot Cost_{jz})\right] = 0 \tag{12}$$

4.4 Interaction between State and Federal Regulators

The regulator can orient the pricing of local telephone services to obtain funds from the federal Lifeline and High Cost Model programs described in Section 3 and Appendix A. I incorporate the federal Lifeline program by redefining the low income profit $\pi_{jz2}(\widetilde{p}_{z2}, .)$ as:

$$\pi_{jz2}(\widetilde{p}_{z2}, .) = (p_z(m) + \widetilde{p}_{z2}(c) \cdot r_s - mc_{jz}) \cdot D_{jz2} - L(d_z(m) \cdot D_{jz2}) - K_{jz}/2 \tag{13}$$

where $L(.)$ is a C^1 function representing the state cost of Lifeline subsidies. In the base case in (6), $L(d_z(m) \cdot D_{jz2}) = d_z(m) \cdot D_{jz2}$, and the total cost of the Lifeline subsidy is fully internalized at the state level. A general form for $L(.)$ allows the state cost, $L(d_z(m) \cdot D_{jz2})$, to diverge from the actual amount of subsidy, $d_z(m) \cdot D_{jz2}$. For example, the federal Lifeline funds might not be computed as a cost by state regulators and $L(d_z(m) \cdot D_{jz2}) \leq d_z(m) \cdot D_{jz2}$. In Section 5.2, I use the information on the federal Lifeline program to approximate $L(.)$.

The participation in the high cost program adds a separate correction HCS_s for the profits of a state s. These states will receive a subsidy per telephone line equal to 76% of the excess of the average cost per line over the national benchmark. Formally,

$$HCS_s = \left(\sum_{z=1}^{Z_s}\sum_{j=1}^{N_{zs}} l_{jz} + l_s\right) \cdot 0.76 \cdot \max\left(\frac{\left[\sum_{z=1}^{Z_s}\sum_{j=1}^{N_{zs}} TC_{jz} + TC_s\right]}{\left[\sum_{z=1}^{Z_s}\sum_{j=1}^{N_{zs}} l_{jz} + l_s\right]} - nb, 0\right)$$

where l_{jz} (TC_{jz}) denotes the number of residential lines (total cost) of the regulated firm in local market jz and l_s (TC_s) denotes all other telephone lines (total cost) in state s. The nb term denotes the national benchmark for the monthly cost per line (\$23.35). I assume that the expected number of lines in local market jz will equate expected demand so $E[l_{jz}|\iota_s] = D_{jz1} + D_{jz2}$. For a state in the high cost program, the expected marginal profit $E[\partial\pi_{jzg}(.)/\partial p_z(m)|\iota_s]$ is then corrected with the following term:

$$\frac{\partial HCS_{jzg}}{\partial p_z(m)} = 0.76 \cdot (mc_{jz} - nb) \cdot \frac{\partial D_{jzg}}{\partial p_z(m)} \tag{14}$$

This implies that increasing the number of lines in local markets below (above) the national benchmark cost per line reduces (increases) the total high cost contribution to the state. The variation of the discount $d_{zg}(m)$ also affects the number of lines so $\partial HCS_s(.)/\partial d_{zg}(m)$ can be calculated analogously. In year 2000, all the states in the sample that participated in the hold-harmles program had stopped receiving these subsidies. I include the description of the hold-harmless adjustment in Appendix A for completeness, but it will not affect estimation. The incorporation of the Lifeline and Linkup adjustments to the first order conditions in (9) and (10) yields the equations:

$$E\left[\sum_{j=1}^{N_{zs}}\sum_{g=1}^{2}\left(\frac{\partial CS_{jzg}(.)}{\partial p_z(m)} \cdot \frac{\lambda_{zg}}{1+\mu_s} + \frac{\partial \pi_{jzg}(.)}{\partial p_z(m)} + \frac{\partial HCS_{jzg}}{\partial p_z(m)}\right) \mid \iota_s\right] = 0$$

$$E\left[\sum_{j=1}^{N_{zs}} \frac{\partial CS_{jz2}(.)}{\partial d_z(m)} \cdot \frac{\lambda_{z2}}{1+\mu_s} + \frac{\partial \pi_{jz2}(.)}{\partial d_z(m)} + \frac{\partial HCS_{jzg}}{\partial d_{zg}(m)} \mid \iota_s\right] = 0$$

where expectations of $\partial\pi_{jz2}(.)/\partial p_z(m)$ and $\partial\pi_{jz2}(.)/\partial d_z(m)$ are now given by:

$$\begin{aligned} E\left[\partial\pi_{jz2}(.)/\partial p_z(m) \mid \iota_s\right] &= -\frac{\partial L(d_z(m)\cdot D_{jz2})}{\partial p_z(m)} \\ &\quad + D_{jz2} + \frac{\partial D_{jz2}}{\partial p_z(m)}\cdot\left(p_{z2}(m) + \widetilde{p}_{z2}(c)\cdot r_s - \gamma\cdot Cost_{jz}\right) \end{aligned}$$

$$\begin{aligned} E\left[\partial\pi_{jz2}(.)/\partial d_z(m) \mid \iota_s\right] &= -\frac{\partial L(d_z(m)\cdot D_{jz2})}{\partial d_z(m)} \\ &\quad + \frac{\partial D_{jz2}}{\partial d_z(m)}\cdot\left(p_{z2}(m) + \widetilde{p}_{z2}(c)\cdot r_s - \gamma\cdot Cost_{jz}\right) \end{aligned}$$

5 Estimation

The approach employed to identify and estimate the parameters of the model (α, β, γ, ϕ) relies on the orthogonality of unobserved demand and supply shocks (ξ, ω, η) to exogenous geographic, demographic and political factors. Given demand side instruments (W), cost shifters $(Cost)$ and policy shifters (Pol), the set of orthogonality conditions $E\left[\xi\cdot W\right] = 0$, $E\left[\omega\cdot Cost\right] = 0$ and $E\left[\eta\cdot Pol\right] = 0$ can be used to derive a GMM estimator of the parameters, as in Hansen (1982) and Newey and Mcfadden (1994). I also use simulation to form the sample analogs to demand moments $E\left[\xi\cdot W\right]$. This follows the empirical strategy introduced by Berry (1994) and BLP (1995). Pakes and Pollard (1989) and Mcfadden (1989) provide a general framework for estimation with simulated moments.

The formal model in Section 4 must be a good description of the actual price setting process of the regulator to identify correctly the regulator's weights λ and the parameters ϕ controlling the relation between weights λ and policy variables Pol. For example, the exclusion of unobserved legal constraints will affect the estimates of λ, and it is then possible to attribute the observed prices to unequal welfare weights when these prices are indeed determined by the legal constraints. Examples of these potential constraints are legal limits to the creation of price zones or to the ability to set different low income subsidies in different geographic zones. If this misspecification problem is present, the estimates of λ would still be an informative index of the departure from Ramsey pricing, but they could not be interpreted as preferences weights. This is a common limitation of structural estimation. The classical studies of market competition of Bresnahan (1982) and Lau (1982), reviewed for example in Perloff et al. (2007), estimate the conjectural variations of firms under their maintained assumptions, but these estimates can be interpreted more generally as measures of price-cost margins.

The methodology is detailed next with the main steps including (i) recovery of (ξ, ω, η) (ii) choice of instruments and (iii) and moment construction.

5.1 Recovering the Shock on Demand

I define $n \in \{1, ..., N\}$ as an index over the total number of local market observations, where $N = \sum_{s=1}^{S} \sum_{z=1}^{Z_s} N_{zs}$. I estimate the telephone penetration implied by the model in (3) with the simulation of a sample of $H = 100$ households for each local market n. The empirical distribution of household income $\widetilde{F}_n(I)$ from the US Census (2000) is used to generate the simulated income samples. Given $(\widetilde{I}_i)_{i=1}^{H}$, it is possible to generate a sample $(\widetilde{\alpha}_i, \widetilde{p}_{in})_{i=1}^{H}$ of individual household price coefficients and net prices given the specification in Section 4.1. Assuming knowledge of (x_n, ξ_n, Θ_D), I can obtain the following simulated analog of (3):

$$\widetilde{P}_n(x_n, \widetilde{p}_n, \xi_n, \Theta_D) = \frac{1}{H} \cdot \sum_{i=1}^{H} P_{in}(x_n, \widetilde{p}_{in}, \xi_n, \widetilde{\alpha}_i, \Theta_D)$$

The estimation algorithm considered in BLP(1995) computes next the mean market value δ_n with the equality of the simulated model penetration $\widetilde{P}_n$ with the actual penetration level s_n. The estimate of $\widehat{\delta}_n$ makes immediate to extract $\widehat{\xi}_n = \widehat{\delta}_n - x_n\beta$. I solve for $\widehat{\delta}_n$ by iteration steps of the form:

$$\delta_n^{it+1} = \log(s_n) - \log\left(\widetilde{P}_n(\delta_n^{it}, .)\right) + \delta_n^{it} \tag{15}$$

This procedure cannot use observations with $s_n = 1$ as the infinite support of ϵ_{in} excludes $\widetilde{P}_{in}(.) = 1$, and (15) neglects that $\widetilde{P}_n(\delta_n, .) \neq s_n$ for finite number of households H. This forces me to discard 264 observations (3.7% of sample). The percentage of observations discarded is low and the small differences in penetration between the full and selected sample shown in Table 1 also reduce the possibility of selection problems.

The iterative procedure in equation (15) can be applied separately to each market,[13] but the speed of the computation increases by use of the standard practice of solving simultaneously for the constants δ in multiple markets. The algorithm employed starts applying the iteration step in (15) to the whole sample of 6854 local markets. After a number of iterations, the algorithm finds the solution $\widehat{\delta}$ for a subset of markets, and iteration step in (15) is further applied only to markets for which a solution $\widehat{\delta}$ has not been reached. See Appendix B for the implementation.

5.2 Recovering the Shock on the Regulator's Weights

The first order conditions in (9) and (10) are the base to form the sample analogs of $E\left[\eta \cdot Pol\right] = 0$. The estimation approach searches for the unobserved weights λ that satisfy (9) and (10) and make prices at least locally optimal. The error η is then recovered by applying on λ the structure in equation (8). The policy shifters (Pol) are divided into a set of state indicators (1_s) and all other policy variables describing observed demographic and political characteristics of the price zones and states (Pol_S).

Local Market Level mc, Group-Zone Level λ

In this section, marginal cost mc is estimated from the HCPM cost data. Appendix C adapts the framework to consider unobserved mc and points to the limits of the information contained in the first order conditions. The total cost value in the HCPM, TC_{HCPM}, is used as a proxy for the true total cost in each local market. It is then possible to estimate a general cost equation:

$$TC_{HCPM,q} = g\left(Cost_q, \gamma\right) + \omega_q \tag{16}$$

[13] Separate computation for each market is also possible when more than one option per market is available. In that case, it is necessary to solve simultaneously for all δ inside a market, as the predicted share of a given option is a function of all δ terms in that market. The problems for the different markets are however still separable.

where $g(.,.)$ is a C^1 function of cost shifters $Cost_q$ and parameters γ. In the application in Section 6, I use a simple specification of $g(.,.)$ linear in γ as in Rosston et al.(2008). The set of cost observations $q \in \{1,...,Q\}$ coincides with the set of all available local markets $n \in \{1,...,N\}$. The HCPM uses a target number of residential lines in each local market, $reslines$, as input to calculate total cost. I derive then the estimate $\widehat{mc}_q$ of marginal cost :

$$\widehat{mc}_q = \partial g\left(Cost_q, \hat{\gamma}\right)/\partial reslines$$

Given a specification of $g(.,.)$ linear in γ, I can obtain $\widehat{mc}_q = \widehat{\gamma}{\cdot}Cost\_mc_q$, where $Cost\_mc_q \subseteq Cost_q$, as not all the cost shifters affecting TC_{HCPM} necessarily shift $\widehat{mc}_q$.

I assume that state regulators use $\widehat{mc}_q$ as best estimate of marginal cost $E\left[mc_{jz} \mid \iota_s\right] = \gamma \cdot Cost_{jz}$ as in (7) and put a different weight λ_{zg} for each zone z and group g as in (8). Given an estimate $\widehat{mc}_{jz}$ of $E\left[mc_{jz} \mid \iota_s\right]$, it is then possible to expand $E\left[\partial\pi_{jzg}(.)/\partial p_z(m) \mid \iota_s\right]$ and $E\left[\partial\pi_{jz2}(.)/\partial d_z(m) \mid \iota_s\right]$ as in equations (11) and (12). For a given z and g, it is immediate to obtain from (9) and (10) that:

$$\frac{\lambda_{z1}}{1+\mu_s} = -E\left[\sum_{j=1}^{N_{zs}} \frac{\partial\pi_{jz1}(.)}{\partial p_z(m)} \mid \iota_s\right] / E\left[\sum_{j=1}^{N_{zs}} \frac{\partial CS_{jz1}(.)}{\partial p_z(m)} \mid \iota_s\right] \tag{17}$$

$$\frac{\lambda_{z2}}{1+\mu_s} = -E\left[\sum_{j=1}^{N_{zs}} \frac{\partial\pi_{jz2}(.)}{\partial d_z(m)} \mid \iota_s\right] / E\left[\sum_{j=1}^{N_{zs}} \frac{\partial CS_{jz2}(.)}{\partial d_z(m)} \mid \iota_s\right]$$

If I substitute for the profit and consumer surplus derivatives in (17), I obtain:

$$\frac{\lambda_{z1}}{1+\mu_s} = 1 + \left[\sum_{j=1}^{N_{zs}} \frac{\partial D_{jz1}}{\partial p_z(m)} \cdot \left(\widetilde{p}_{zg}(m) + \widetilde{p}_{zg}(c) \cdot r_s - \widehat{mc}_{jz}\right)\right] \cdot \frac{1}{\sum_{j=1}^{N_{zs}} D_{jz1}}$$

This expression shows that the presence of positive (negative) markups over cost measure $\widehat{mc}_{jz}$ decreases (increases) the estimated weight, and they do more so the higher the absolute value of $\partial D_{jzg}/\partial p_z(m)$. Note that the presence of the Lagrangian multiplier μ_s prevents the immediate recovery of λ_{zg}. However, I could take the expression in (17) for zone 1 and group

1 as a base to obtain for each group g and zone z the ratio:[14]

$$\lambda^*_{zg} = \frac{\lambda_{zg}}{\lambda_{11}} = \frac{E\left[\sum_{j=1}^{N_{zs}} \frac{\partial \pi_{jzg}(.)}{\partial p_z(m)} \mid \iota_s\right] / E\left[\sum_{j=1}^{N_{zs}} \frac{\partial CS_{jzg}(.)}{\partial p_z(m)} \mid \iota_s\right]}{E\left[\sum_{j=1}^{N_{1s}} \frac{\partial \pi_{j11}(.)}{\partial p_1(m)} \mid \iota_s\right] / E\left[\sum_{j=1}^{N_{1s}} \frac{\partial CS_{j11}(.)}{\partial p_1(m)} \mid \iota_s\right]} \tag{18}$$

For example, a state with two zones will yield four ratios $\lambda^*_{11} = \lambda_{11}/\lambda_{11} = 1$, $\lambda^*_{12} = \lambda_{12}/\lambda_{11}$, $\lambda^*_{21} = \lambda_{21}/\lambda_{11}$ and $\lambda^*_{22} = \lambda_{22}/\lambda_{11}$. An alternative approach would add to Pol_v the state dummies in $1(s)_v$. The index $v \in \{1, ..., V\}$ over the set of all available welfare weights in the data is defined by $V = \sum_{s=1}^{S} 2 \cdot Z_s$ (twice the number of zones). The following welfare weight equation is taken to the data:

$$\log(\lambda_v) - \log(1 + \mu_s) = \sum_{s=2}^{S} \phi_s \cdot 1(s)_v + \phi \cdot Pol\_S_v + \eta_v \tag{19}$$

The state fixed effects ϕ_s control for the effect of $-\log(1+\mu_s)$ and any other possible state-level unobserved heterogeneity. These fixed effects are estimated by including the $(1 \times (S-1))$ vector of state dummy variables $1(s)_v$. The inclusion of state fixed effects ϕ_s also limits the variables that can be included into the set of all other policy variables (Pol_S_v). For example, the coefficient on a state dummy for a directly elected regulator $(Elected_v)$ can not be separately identified from the state fixed effect. However, it is possible to identify the differential effect of $Elected_v$ on the weights of low income consumers with the inclusion of $Elected_v \cdot I_{poor,v}$. The variable $I_{poor,v} \subseteq Pol\_S_v$ is an indicator for λ_v corresponding to the low income group and it avoids the perfect correlation with the state dummies $1(s)_v$.

Local Market Level mc, Group-Zone Level λ and Federal Interaction

I modify the previous specification to introduce the state incentives to obtain federal subsidies in Section 4. I use the actual design of the Lifeline program to form two different approxima-

[14] The ratio in (18) assumes a group g that is not eligible so the derivatives $\partial \pi_{jzg}(.)/\partial p_{zg}(m)$ and $\partial CS_{jzg}(.)/\partial p_z(m)$ are used. If the group is eligible, I use derivatives with respect to d_z.

tions to the function $L(.)$ for the state cost of this subsidy. The specification $Federal\ I$ appends at a local market jz with a discount $d_z(m) \leq \$10.5$ the following correction to $\partial\pi_{jz2}(.)/\partial d_z(m)$:

$$\frac{\partial L(d_z(m) \cdot D_{jz2})}{\partial d_z(m)} = \frac{2}{3} \cdot \left[(d_z(m) - 5.25) \cdot \frac{\partial D_{jz2}}{\partial d_z(m)} + D_{jz2}\right] \tag{20}$$

The term in (20) is the marginal state cost at local market jz of increasing the Lifeline discount $d_z(m)$. This derivative captures the federal matching of state Lifeline contributions described in Section 3.1 and Appendix A. Federal matching reduces the marginal state cost of the subsidy to 2/3 of the marginal increase in total subsidy dollars. Federal funds also cover a basic level of Lifeline subsidy equal of \$5.25 and reduce the gross state subsidy contribution to $d_z(m) - 5.25$. The federal matching applies as long as the discount $d_z(m)$ does not exceed the program cap of \$10.5. I use a different correction at local markets with $d_z(m) > \$10.5$:[15]

$$\frac{\partial L(\ d_z(m) \cdot D_{jz2}\ )}{\partial d_z(m)} = \left[\frac{2}{3} \cdot (10.5 - 5.25) + (d_z(m) - 10.5)\right] \cdot \frac{\partial D_{jz2}}{\partial d_z(m)} + D_{jz2} \tag{21}$$

The correction in (20) applies for all states except Massachusetts, Maryland and Rhode Island, which have Lifeline subsidies significantly above the matching region. In $Federal\ I$, states at the margin (a subsidy level at the minimum $d_z(m) = 5.25$ or at $d_z(m) = 10.5$) are assigned the marginal state cost in (20). This is the minimal approximation to the marginal state subsidy cost at the margin and it can overstate the federal portion of the subsidy.

The specification $Federal\ II$ assigns a lower fraction of federal funds to the 17 states that set $d_z(m)$ at the margin. The specification $Federal\ II$ is the maximal approximation to the marginal subsidy cost at the margin and it might understate the federal portion of the subsidy. This is the opposite case to specification $Federal\ I$. States with a contribution $d_z(m) = 10.5$ are assigned now a correction equal to (21) rather than (20). States with a contribution equal to the minimum $d_z(m) = 5.25$ are also assigned the full marginal cost of the subsidy, which is in this case:

[15] Given the scheme described in Appendix A, the total state Lifeline subsidy d_{sz} for a choice of total subsidy d_z in $[\$5.25, \$10.5]$ is given by $d_{sz} + 0.5 \cdot d_{sz} = d_z - \$5.25 \rightarrow d_{sz} = (2/3) \cdot (d_z - \$5.25)$.

$$\frac{\partial L(\ d_z(m)\cdot D_{jz2}\ )}{\partial d_z(m)} = (d_z(m) - 5.25)\cdot\frac{\partial D_{jz2}}{\partial d_z(m)} + D_{jz2}$$

The correction for the high cost program participation described in sections 3.2 and 4.4 is straightforward. I append a term as in (14) to the marginal profit expressions in (9) and (10) for the participating states. There is no need to adjust the profits of states receiving hold-harmless contributions since these subsidies were not received after year 2000 for the hold-harmless states in the sample (AR, CO, KY, NM, SC).

5.3 Identification

This section outlines how the data sources are used to identify and estimate the different parameters. I refer the reader to Section 3 and Appendix A for the full description of the variables.

The variation in the cross section of demographics (ethnic groups, total number of households, etc.) identifies demand parameters in β. As for the price coefficients α, I rely on price and income distribution variation across local markets. For local markets with comparable prices and demographics (excluding income), the difference in the distribution of income contributes to explain differences in penetration levels. The coefficients $\alpha(m)$ and $\alpha(c)$ are separately identified through the fact that monthly prices are a recurrent cost for households whereas the connection charge is a one-time payment. Monthly prices are not exogenous, but endogenously chosen by the regulator, so I use the constrained optimization problem of the regulator as a basis to find instruments that are correlated with prices but not with the unobserved mean value ξ.

Suitable demand instruments W include political variables Pol that affect the weights on consumers λ, and therefore prices, but not the local demand for telephone. Thus, I include in W: *Elected*, $\%\ Dem - PUC$, and *% Dem-Leg*. Similarly, *Business/Residential Ratio* and $Competition$ 95 affect the slackness of the profit constraint of the regulated ILEC, and therefore prices, but can be assumed uncorrelated with the demand unobservable ξ. The state averages of included demographic regressors in x can also be added to W. Prices in every local market are connected to the demand conditions in all other locations in the state through the presence of the common budget constraint. At the same time, the average demographic conditions in a state (excluding local market n) can be assumed uncorrelated with the unobserved mean value in local market n. A parsimonious set of state controls includes *state asian %*, *state average income*, *state income flag* (indicator controlling whether the average state income is above the national average), *state % rural* and the interaction $\%\ Rural \cdot \%\ Dem - PUC$. The HCPM cost measures are redundant given their correlation with geographic variables. Leverage is not a valid instrument as firms plausibly choose debt as a function of demand and cost conditions.

The weights λ are identified by the assumption of optimality of observed prices and the regulation model developed in Sections 4 and 5. The HCPM cost data is used to estimate marginal cost in every local market.

Cost and political shifters include geographic and political factors that can be taken as exogenous from unobserved conditions in the telephone market such as $Total\ hhs(k)$, *Density*, % *Rural* or % *Poor*. The variation of these exogenous variables with respect to weights and marginal costs identifies the parameters γ and ϕ.

5.4 GMM Estimator

The derivation above allows to construct a GMM estimator, as in Hansen(1982), based on the moment conditions $E[\xi \cdot W] = 0$, $E[\omega \cdot Cost] = 0$ and $E[\eta \cdot Pol] = 0$ stated at the beginning of this section. The sample analogs of the moment conditions are collected into the vector $f \equiv (f_W, f_{Cost}, f_{Pol})$ where:[16]

$$f_W = \frac{1}{N} \cdot \sum_{n=1}^{N} \widehat{\xi}_n \cdot W_n$$

$$f_{Cost} = \frac{1}{Q} \cdot \sum_{q=1}^{Q} \widehat{\omega}_q \cdot Cost_q$$

[16] The exogenous shifters ($Cost$, Pol) and errors(ω, η) in the cost and policy moments depend on the choice of model. The cost moment f_{Cost} is derived from (16) if HCPM data is used. If mc is directly backed from (9) and (10), f_{Cost} is derived from (26) and (28).

$$f_{Pol} = \frac{1}{V} \cdot \sum_{v=1}^{V} \widehat{\eta}_v \cdot Pol_v$$

The system formed by the demand moments f_W is overidentified so it is not possible to make f exactly equal to zero. I solve then the program $\min\limits_{\Theta_D, \Theta_S} f^T \cdot \Omega \cdot f$ where Ω is a robust positive definite weight matrix.[17] I provide details on the standard errors in Appendix D.

6 Results

6.1 Logit Demand Model

I present first a simple logit specification of demand without income effects as reference point for the rest of results. Individual heterogeneity is limited to the idiosyncratic shocks ϵ_{in}. The mean value of service δ_n in a local market n is derived from the analytic inversion $\delta_n = \ln(s_n) - \ln(1 - s_n)$ used since at least McFadden (1974). The first column of the *All households* panel of Table 3 contains the OLS estimates for demand parameters β, where demand shifters include local market demographics, the number of households in the local calling area ($LCA\ hhs$), regular prices (*Monthly_ 50, Connection*) and subsidies (*Subsidy_ 50, Subsidy_ Connection*). The subsidies are obtained as the difference of the regular and discounted prices, e.g., *Subsidy_ 50 = Monthly_ 50 - Monthly_ 50 (sub).* As in Ackerberg et al. (2008), I present the results for *Monthly_ 50*, as it is a conservative measure of basic access prices. Results for *Monthly_ 100* are comparable. The standard errors $Sd(\beta)$ are robust to heterocedasticity and clustering of arbitrary form at the state level.

The OLS price coefficients in Table 3 are all insignificant. However, the potential endogeneity of *Monthly_ 50* and *Monthly_ 50 (sub)* make OLS results biased and inconsistent. The OLS estimator ignores the positive correlation between prices and unobserved service quality and creates a bias toward zero in the price coefficients, as known from the empirical product differentiation literature. The connection prices are plausibly exogenous as they are set at the

[17] Ω is chosen a block diagonal matrix containing 2SLS weight matrix for the demand moments $\left(\sum W_n^T \cdot W_n\right)^{-1}$ and OLS weights for cost, $\left(\sum Cost_q^T \cdot Cost_q\right)^{-1}$, and policy moments,$\left(\sum Pol_v^T \cdot Pol_v\right)^{-1}$.

state level and represent a small dollar amount. It is then unlikely that the connection charge is based on detailed analysis of local demand conditions. Also, endogeneity tests in Appendix E do not provide evidence of endogenous connection prices. Strength and validity analysis of the instruments is also provided in Appendix E.

The importance of controlling for racial factors suggested in the previous literature, Taylor et al. (1990), Riordan (2002) and Ackerberg et al. (2008), is confirmed with negative and significant coefficients for $\%Black\ hhs$, $\%Native\ hhs$ and $\%Other\ hhs$. The coefficients on $\%Rural$ (-0.36), $\%MSA$ (0.25) and $Median\ hh\ income$ (0.04) point to the reasonable result of higher demand for local telephone in wealthier and more urban communities.

The *IV* column of the *All households* panel in Table 3 considers endogenous *Monthly_50* and *Subsidy_50* and it uses the set of instruments in Section 5.3 above to obtain 2SLS estimates. The correction of the endogeneity bias leads to increased price coefficients, *Monthly_50* (-0.077) and $Subsidy$_50 (0.061). The higher price coefficients lead to an increase of the average elasticity[18] of telephone penetration with respect to $Monthly$_50 from (0.004) to (0.016). Interestingly, the elasticity for the OLS estimates is close to the result of 0.005 in Hausman et al. (1993), which abstracts from endogeneity problems, and the significant increase in elasticity from accounting for endogenous prices is also observed in Ackerberg et al. (2008).

The $Poor\ Households$ panel in Table 3 reproduces the analysis above only for poor households assuming that they make use of the subsidized prices $Monthly$_50(sub) and *Connection (sub)*. This coincides with the approach in Ackerberg et al. (2008) to control for the different price elasticity and price schedule of low income consumers. The results are qualitatively comparable to the *All households* panel, but the magnitude of the coefficients changes. In particular, I observe higher price elasticity (0.024) with respect to $Monthly$_50(sub), as expected in the low income group.

[18]Elasticity at each wire center n is calculated at $\delta = x\beta$ for service value. A single measure is formed by averaging wire center elasticities with the wire center's share of total or poor households as weight. The same weighting is applied in subection 6.2 ahead.

6.2 Logit Demand Model with Individual Income Effects

This section presents the results of the full demand model described in Section 4.1. The estimates of the demographic controls do not differ significantly from the basic logit model. The interest of the full model is rather in the possibility of estimating a different marginal price effect for each level of income and assigning to each household the net price corresponding to its eligibility for Lifeline and Linkup. The variables $\widetilde{p}_{in}(m)$ and $\widetilde{p}_{in}(c)$ are obtained by subtracting the *Lifeline* and *Linkup* discounts, $Subsidy\_50$ and $Subsidy\_Connection$, from regular prices $Monthly\_50$ and $Connection$ only for eligible low income consumers.[19] The results are presented in column (a) of Table 4. The effect of monthly prices $\widetilde{p}_{in}(m)$ is negative and significant (-0.382) whereas the connection charge is negative but not significantly different from zero (-0.068). From the demand model, a household with income (in thousands) I_i will have price sensitivity coefficient $-0.382/I_i$. With this figure, I can compute a different elasticity for each household in a given local market.

Figure 1 presents the elasticity of the probability of adoption to price $\widetilde{p}_{in}(m)$ for income levels ranging from $\$5,000$ to $\$40,000$, with the mean value of service $x\beta$ at the sample median values of x. Elasticity declines quickly as the level of income of the household increases and it is significantly higher for the lowest income levels.[20] The use of average elasticity masks this variation across income levels. The average market demand elasticity for *All households* is (0.017), which represents an intermediate value between the elasticities for households in the low income (0.055) and normal income (0.002) groups. A Wald test for the difference of the elasticity for $Normal\ Income\ households$ and $Low\ Income\ households$ rejects the hypothesis of a zero difference between the average elasticities of these two groups.

Figure 2 presents the results for a particular local market (observation 73 in South Carolina) in the sample, with relatively low penetration (0.88). The pattern of elasticities is similar to the

[19] I choose $I_i \leq \$20,000$ to classify a household as low income. Poverty threshold in 2000 ranged from $\$8,350$ to $\$17,050$ for households of size from 1 to 4 in the poverty guidelines. Eligibility for Lifeline and Linkup varies for each state but it is usually laxer than proof of poverty status (income at or below 135% or 150% of the poverty line,participation in welfare programs). It is not possible to control perfectly for eligibility with aggregate data but it is possible to check for the robustness of the results to different assumptions.

[20] Elasticty for households with income below $\$5,000$ ranges from 4.94 to 0.05. These levels were not included in order to preserve a proper scale in the figure.

calculation for the hypothetical local market in Figure 1 but the levels are higher. For example, a household with an income of $\$24,000$ exhibits an elasticity close to 0.05 in the local market in Figure 2 whereas it presents an elasticity below 0.01 for the hypothetical local market in Figure 1.

The model estimates in column (b) of Table 4 account for the fact that participation in the subsidy programs is below 100% by assigning the discounted prices in every market only to a fraction of eligible consumers equal to the participation rate in the Lifeline program at the state level. This leads to a reduction of the estimated price coefficient to (-0.322). The coefficient for the connection turns positive (0.02) but it cannot be statistically distinguished from zero. This reduction in the price coefficient is translated into a small change in the elasticities for *All households* (0.016) and *Low Income households* (0.054). Alternative specifications based on the price proxy $Monthly\_100$ also yield comparable results. Given the robustness of the results to the correction of the participation rate in $Lifeline$, I will use the base specification in column (a) of Table 4 for the remaining sections.

6.3 Expected Marginal Cost

I examine different cost specifications linear in parameters γ to estimate the regulator's expected marginal cost $E\left[mc_{jz} \mid \iota_s\right]$. Cost shifters $Cost_p$ include the HCPM targets for residential, business and special access lines (*Res Lines, Bus Lines, Sa Lines*), geography (*Area* in squared miles, *% Rural, %MSA*) and interactions. The HCPM target lines are valid exogenous regressors because they are based on population data and target levels of service in the HCPM rather than actual demand.

The results reproduce the cost estimation in Rosston et al. (2008) and the method is comparable to the estimation approach put forward in Gasmi et al. (2002). I report in Table 5 a representative subset of the cost estimates. Column (a) presents OLS results for a regression of total cost on the numbers of the different types of telephone lines. This regression provides the average marginal cost for each type of line across the sample. In column (b), I add interactions with *Area* (*Area·Res Lines, Area·Bus Lines...*) and, in column (c), I add interactions between the different types of lines (*Res Lines·Bus Lines, Res Lines·Sa Lines*). This is a simple implementation of equation (16), where function $g(\gamma, Cost_n)$ is assumed linear in the parameters. For example, the model in column (a) is given by:

$$TC_{HCPM,\ q} = \gamma_0 + \gamma_1 Res\ Lines_q + \gamma_2 Bus\ Lines_q + \gamma_3 Sa\ Lines_q + \gamma_4 Area_q + \omega_q$$

For this simple model, the marginal cost $\widehat{mc}_q$is simply equal to $\widehat{\gamma}_1$. The estimates of $\widehat{mc}_q$ in columns (b) and (c) are obtained analogously. In all specifications, the average estimated marginal cost is close to \$23 with a maximum standard error of \$ 2.6. Table 5 contains summary statistics of $\widehat{mc}_q$ for the different specifications.

6.4 Regulator´s Welfare Weights

I estimate welfare weights following the method presented in Section 5.2. For the cost estimates $\widehat{mc}_q$, I use two specifications: (i) the MC specification considers marginal cost equal to the estimates from model (b) in Table 5 and (ii) the AC specification considers marginal cost equal to HCPM average cost. This second specification checks for the robustness of the results to the assumptions on $E[mc|\iota_s]$. The average cost is a crude but readily available proxy for the actual marginal cost per line, and it is of interest to examine the weights required to rationalize prices for a regulator that uses this cost approximation.

The panel *Base scenario* of Table 6 contains the results for the model with full internalization of subsidy costs by state regulators. The policy controls include I_{Poor}, which is an indicator for whether a given weight corresponds to the low income group. This indicator I_{Poor} is interacted with other policy shifters, e. g., *Elected* (Direct Election) or the price zone average of $\%$ *Rural*, to capture the differential effect of these variables on the weight of the low income group. The estimates are qualitatively comparable between the AC and MC specifications so I focus on the latter.

I observe that the estimated weight on the general (poor) population decreases (increases) in poor areas given significant estimates $\%\ Poor$ (-0.18) and $\%\ Poor \cdot I_{Poor}$ (0.79). I do not find strong evidence in favor of the presence of rural bias with insignificant estimates $\%\ Rural$ (0.003) for the general population and $\%\ Rural \cdot I_{Poor}$ (0.042) for the low income consumers. The coefficients on the rural population factors are however significant for the AC specification, as the higher imputed marginal cost per line in rural areas requires a higher weight on rural consumers to rationalize prices. The suppression of the downward bias for regular consumers in poor areas would lead to lower regular local telephone prices in accordance with the lower value of the service in those areas. On the contrary, poor consumers would observe an increase in subsidized prices if the bias is eliminated.

The importance of weight biases is moderated by the fact that the Wald test *W-test Weights* fails to reject that the sum of squared weight differences in the sample is zero for both the AC and MC specifications. The Figure 3 plots the sorted differences in welfare weights and error bands for the MC specification. The figure also suggests that the observed welfare weight differences are not significantly different from zero, but $W-test\ Weights$ provides more formal evidence.

The specifications in $Federal\ I$ and $Federal\ II$ modify the regulatory problem to accommodate the possibility that state regulators do not internalize fully the federal cost of subsidy programs. As described in sections 4.3 and 5.2, the specification in $Federal\ I$ provides to state regulators stronger incentives than $Federal\ II$ to increase the telephone use among low income households. The previous results on the effect of $\%\ Poor$ on weights are reversed. In areas with higher percentage of poor population, I observe now higher weight in favor of the general population and less weight in favor of low income population. The federal Lifeline program makes price subsidies less costly for state regulators, and the new estimated weight differences are required to rationalize that the observed discounted prices are not lower.

The conclusions under $Federal\ I$ are qualitatively robust to the specification of marginal cost so I will focus again on MC. In Table 6 $Federal\ I\ MC$, I observe the estimates $\%\ Rural$ (-0.012), $\%\ Poor$ (0.88), $\%\ Rural \cdot I_{Poor}$ (0.064) and $\%\ Poor \cdot I_{Poor}$ (-0.514). Only $\%\ Poor$ and $\%\ Rural \cdot I_{Poor}$ are statistically significant in this subset of coefficients. The higher weight for poor consumers in zones with higher $\%\ Rural$ survives the change from $Base\ scenario$ to $Federal\ I$. It is interesting to note that the estimates for $\%\ Rural \cdot I_{Poor}$ (0.38) in the AC specification also remain positive and significant. The federal Lifeline program reduces the cost of extending service in a given state, but the average cost in rural areas remains high so a high relative weight on the poor consumers of these areas is still required to rationalize prices. Another interesting result is that democrat regulators are assigned higher weights for low income consumers with significant coefficients $\%\ Dem - PUC \cdot I_{Poor}$ (0.05) and $\%\ Dem - Leg \cdot I_{Poor}$ (0.29). The $W - test\ Weights$ rejects now the hypothesis of no systematic weight differences across consumer groups. More informally, the Figure 4 shows how the weight differences for MC are bigger in the $Federal\ I$ specification.

The results for the $Federal\ II$ specification in Table 7 are comparable to $Federal\ I$ but the magnitude of the bias changes. For specification MC, I observe estimates $\%\ Rural$ (-0.08), $\%\ Poor$ (0.82), $\%\ Rural \cdot I_{Poor}$ (0.17) and $\%\ Poor \cdot I_{Poor}$ (-0.65). All theses coefficients are significant with the exception of $\%\ Rural$. It is noteworthy that the coefficient on $\%\ Rural \cdot I_{Poor}$ stays positive across all specifications pointing towards the robustness of the rural poor bias. However, the size of $\%\ Rural$ is relatively small when compared with the effect of poor population $\%\ Poor \cdot I_{Poor}$ and the rural bias is then not the main distortion in weights. The differences in weights are large enough for $W-test\ Weights$ to reject that there is no systematic bias. Figure 5 provides a graphical representation of this argument.

Observation of the coefficients for $\%\ Poor$ and $\%\ Poor \cdot I_{Poor}$ in $Federal\ I$ and $Federal\ II$ reveals that both specifications imply that the regulator is favoring the general population (positive coefficient on $\%\ Poor$) in areas with high percentage of poor population at the expense (negative coefficient on $\%\ Poor \cdot I_{Poor}$) of the low income population. This result might be due to the preferences of the regulator but it is also possible that unobserved legal and political constraints prevent state regulators from taking full advantage of the federal Lifeline program. If this is the case, λ cannot be interpreted as pure welfare weights but just as an index of the distortion away from total consumer surplus maximization.

The effects of political controls $Elected \cdot I_{Poor}$, $\%\ Dem - Leg \cdot I_{Poor}$ and $\%\ Dem - PUC \cdot I_{Poor}$ turn bigger and more significant in the $Federal\ II$ specification. The signs are as expected with the exception of % $Dem - Leg \cdot I_{Poor}$ (-0.61). Given the lower speed of law making relative to PUC decisions, % $Dem - Leg \cdot I_{Poor}$ might not be directly connected with the configuration of the PUC and it proxies for some state characteristic. More generally, political variables might identify states with subsidies at the margin of the federal matching region described in Section 4.4, which have different marginal profit functions under $Federal\ I$ and $Federal\ II$.

7 Policy Experiment

In this section, I examine the direct welfare effects of (i) the realignment of residential telephone prices with costs and (ii) the elimination of federal subsidy programs and welfare weight differences across consumers. The model in Section 4 allows me to calculate the adjustment of residential demand, revenues and variable costs to these price changes. The simultaneous control for demand and cost factors is important. For example, optimal prices for high cost areas in a state do not necessarily match the full average cost in those areas if consumers there also exhibit a relatively weak demand.

This study takes as exogenous the locations of state telephone networks and focuses on price variations. A different research project would consider the suppression of some local networks to eliminate all the associated avoidable costs. Political and legal restrictions make this downsizing policy very difficult to implement. Additionally, the telephone network is already in place and a portion of the fixed costs is sunk, making more important to examine the price choice that maximizes welfare for this configuration.

The policy experiment only considers an adjustment of residential telephone prices rather than the full price structure of telecommunication services in each state. These limited policy options are close to the choice set of a state regulator that sees how competition limits its influence outside the residential segment.[21] This exercise is therefore relevant for regulators with limited price power.

[21] The determination of wholesale prices is an alternative policy tool available to the regulator that is out of the scope of the current exercise. See Rosston et al. (2008).

7.1 Cost Pricing Rules

I calculate the welfare changes associated to a realignment of prices with marginal and average costs. These are simple rules that do not require solving an optimization problem and I present them first to set the structure of the counterfactual exercises. The current residential prices generate a deficit and the realignment with cost implies a price increase and a demand contraction, which brings both lower revenues and variable costs for the firm. The full set of results is presented in Table 8.

Marginal cost pricing maximizes welfare for a given network of local markets so I observe that the increase in the sum of welfare for of all the states $\Delta W = \$16.25$m is greater for this policy versus $\Delta W = \$10.5$m for average cost pricing. Given that the sample comprises a substantial portion of the local telephone market in the US (68m households), this represents a small welfare distortion even if measured in annual terms: \$195m and \$126m for marginal and average cost pricing.

The changes in consumer surplus and profits are significantly higher with $\Delta\pi = \$717$m and $\Delta CS = -\$700.5$m for marginal cost policy and $\Delta\pi = \$714$m and $\Delta CS = -\$703.6$m for average cost policy. All these results are driven by the low average elasticity of demand. As prices increase from the current level, the consumers do not drop the service in significant numbers. The higher tariffs then increase the return that the firm obtains from each household of a network with an approximately constant size. The average reductions in penetration in a $[0, 1]$ scale are $\Delta P_n = -0.026$ and $\Delta P_n = -0.027$ for marginal and average cost pricing. The decrease in expected penetration among low income households is substantially higher. For example, $\Delta P_n = -0.103$ for the marginal cost pricing policy.

The small variation in total welfare seems to imply that the allocation problem associated to the tariff choice is to be guided by equity considerations. However, the elimination of the deficit can allow to reduce the distortions in other sectors of the economy (business local telephone sector, long distance telephone sector, etc.) and lead to higher efficiency gains. It is not possible for me to estimate these gains precisely with the current data set. Some basic calculations can be performed with an estimate of the social cost of local telephone deficit. With a public funds multiplier of 1.3,[22] the additional efficiency gain associated with the reduction of deficit is \$ 215m for marginal cost pricing and \$ 214.2m for average cost pricing. The annual equivalents of these amounts are significant and approximately equal to \$ 2.6bn.

7.2 Alternative Regulators

I examine here the pricing policies that would be implemented by a regulator with no bias across consumers and without the distortion of the federal subsidy program. This regulator will set optimal Ramsey prices given a minimum profit requirement. If this profit restriction is set equal to the current level of deficit from the residential telephone sector, the welfare optimization problem corresponds to a regulator that tries to make use of the allowed deficit to maximize unweighted total consumer surplus. If the profit requirement is set equal to the total cost of residential service, the prices set by the regulator will implement the optimal deficit reduction.

Optimal prices will still vary across the geographic zones as the demand and cost conditions are different in these areas. I have described in Section 3 how different prices are set for each actual price zone and that this geographic unit aggregates multiple local markets. I will keep pricing at the zone level in *Zone Regulator* experiments and introduce pricing at the local market level in *Multi Market Regulator* experiments. This will provide the additional benefit of measuring the welfare impact of allowing for broad geographic price discrimination.

The elimination of the different consumer weights and the federal subsidy program while maintaining a constant deficit leads to a decrease in prices for the general population that is partly compensated by an increase in the prices for the low income group. The rationale of this price adjustment is that a household with median income is not likely to drop the service given a price increase and its expected consumer surplus decreases more than the corresponding surplus of a low income household. In the scenario *Zone Regulator I*, I observe price variations

[22] Snow and Warren (1996) find this is as an average estimate of the cost of public funds for OECD countries.

$\Delta\widetilde{p}_{1n}(m) = -\$3.9$ and $\Delta\widetilde{p}_{2n}(m) = \$17.5$. This policy change improves efficiency, $\Delta W =$ \$13.3m, but the reduction of base rates at the expense of the low income consumers poses a political challenge. The results in *Multi Market Regulator I* exhibit additional welfare gains associated to the added pricing flexibility with $\Delta W =$ \$ 15.8m. The full set of outcomes is in panels (a) and (c) of Table 9.

The scenario in *Zone Regulator II* sets the profit requirement of the firm as high as to cover the portion of costs allocated to residential service according to the following average cost rule:

$$\overline{\pi}_s = \sum_{z=1}^{Z_s} \sum_{j=1}^{N_{zs}} ac_{jz,HCPM} \cdot D_{jzg}$$

where $ac_{jz,HCPM}$ corresponds to average cost per line in the HCPM model. The increase in welfare $\Delta W =$ \$13.8m for *Zone Regulator II* is greater than the result for the average cost pricing rule in subsection 7.1. Prices are now adjusted optimally to the demand and cost conditions at the price zone level. The scenario *Multi Market Regulator II* has an associated welfare gain equal to $\Delta W =$ \$ 16.1m, which is very close to the optimal solution of marginal cost pricing. The portion of imputed total cost in excess of variable costs is moderate (a local market average of \$24,000) so the welfare distortion imposed by the need to break even with respect to marginal cost pricing is small. I also notice that there is only a moderate welfare gain from pricing at the local market level rather than at the zone level as in *Zone Regulator* scenarios.

8 Conclusion

This article shows with an empirical study of local residential telecommunication services how structural econometric models can be used to recover regulators's objectives. The analysis requires only public market data and well-understood IV-GMM techniques as in BLP (1995). The presented framework can then be useful for regulators and researchers without micro data and limited resources.

The regulation model separates demand and cost factors precisely from actual differences of regulators's weights across consumers with different incomes and locations. The analysis shows no evidence of a bias in favor of the general population of rural areas but it offers some support for the presence of a bias in favor of poor consumers in rural areas. The estimated effect of the percentage of poor consumers of an area on the relative weights depends on the estimated model. For the realistic assumption that state regulators do not internalize fully the costs of federal low-income subsidies, I observe that low income consumers are disfavored in poor areas. The negative relative bias on low income consumers is compensated in states with a Democrat and direct election PUC by the higher state-wide average weight placed on low income consumers. Under several plausible specifications, a joint test on weight differences rejects the hypothesis that they are systematically equal to zero.

The confirmation of the existence of state regulator bias is important for the implementation of federal policies and it provides some justification for the federal subsidy programs if these are oriented to correct biases in state policy. This information can be relevant for the extension of universal service subsidy programs to wireless and broadband Internet services. The importance of a proper structure of Broadband Universal Service will be increasing as Internet and Internet telephony consolidate further. The experiments in the last section quantify a small direct welfare effect of regulatory bias on local residential services, but an important redistribution between residential consumers and the firm. If the implementation of new subsidy programs is decentralized to state regulators, we can expect the bias across consumers to lead the implemented outcome away from the first best solution. To the extent that the demand for wireless and new Internet services is as inelastic as the demand for local telephone in the past, the direct welfare impacts can also be expected to be moderate. Whether this is effectively the case is a question left for future research as better data on the broadband and wireless sector become available.

A Appendix: Additional Data Description

The first part of the appendix contains the definitions of demographic variables and information on the use of census data. The second part details the data on regulators's characteristics, competition and the price setting process.

A.1 Markets and Demographic Data

The data set is the result of matching the demographic information from the United States Census (2000) to data on regulation policy at the local market level. This combination is made possible by use of Claritas (2003), which contains a cross reference of census block groups, CBGs henceforth, and wire centers. The CBG is the finest geographic level at which the US Census 2000 is disclosed. The average size of a CBG is 1,500 persons.

Local market demographics formed from the United States Census (2000) include total number of households, $Total\ hhs$, classification of total households by race groups, *%Black hhs, %Asian hhs, %Native hhs* and *% Other hhs* (*%White hhs* is recovered by subtracting from one the sum of the percentages for the other races), percentage of rural households, % $Rural$, percentage of poor households, *% Poor hhs*, *Median hh income*, in thousand dollars, and percentage of households in a Metropolitan Statistical Area (MSA), % MSA. A MSA is a geographic entity designated by the Census to represent core urban areas with population of at least 50,000 persons. I use this variable as a proxy for urban development and economic activity.

The United States Census (2000) allows me to construct total telephone penetration (percentage of total households with telephone), $Tel\ Pen\ Total$, and the distribution of income at the local market level. I add this data to the original Ackerberg et al. (2008) data set to characterize the demand conditions for the general population beyond the poor household group analyzed in that article. Telephone penetration for poor households, $Tel\ Pen\ Poor$, is constructed by allocating to CBGs penetration data at the Census Tract level of the US Census 2000. The Census Tract is a broader geographical unit than the CBG.

A.2 Regulators's Characteristics and Tariff Setting

State Regulation

The National Association of Regulatory Utility Commissioners provides in NARUC (2002) data for each state public utility commission (PUC) in year 2000 on the percentage of democrat commissioners, $\%\ Dem - PUC$, and the formation mechanism (election versus appointment of commissioners), *Elected*. This provides a basic political profile for each commission. The percentage of Democrats in the state legislature, *% Dem-Leg*, is added as an additional political control.

Competition in residential local telephone has remained moderate despite the TA 96, with a national average of 2% of residential lines provided by CLECs in year 2000. Entry in local telephone has focused on the business segment, which contains a higher number of sizeable high value customers. The profit derived from the business segment contributes to break even by ILECs and it provides slack to the regulator to maintain low residential revenues. The relative size of the business and residential segments (measured as the rate of business to residential lines in the state), $Business/Residential\ Ratio$, and the degree of competition (measured with the percentage of lines provided by CLECs, percentage of residential lines provided by CLECs and the early presence of local telephone competition in 1995), $\%\ CLEC\ lines\ in$ 1999, $\%\ CLEC\ res.\ lines\ in$1999 and $Competition\ in$ 1995, are proxies for the slackness in the budget constraint faced by the regulator.[23]

The data set contains not only the tariffs described in Section 3.1 but also the line counts employed by the regulators in the tariff setting process. As described in Rosston and Wimmer (2005), state regulators commonly follow a value-of-service methodology to set prices by which they firstly assign wire centers into geographic groups denominated as local calling areas (LCAs), classify the LCAs into rate groups according to the number of lines and then set different prices for different rate groups. Some states follow alternative approaches and assign a

[23] I added to the dataset in Ackerberg et al. (2008) the variables $\%\ CLEC\ lines\ in$ 1999 and $\%\ CLEC\ res\ lines\ in$ 1999 from the FCC Statistics of Common Carriers (1999) and Local Telephone Report (1999). Observations for states with small presence of CLECs are missing due to confidentiality requirements.

single price across the state or allow prices to depend explicitly on costs. The number of million households in each LCA, $LCA\ hhs$, is used as a proxy for network value.

Federal Programs: Lifeline, Linkup and HCPM

In year 2000, the federal regulator provided a basic Lifeline subsidy equal to the federal subscriber line charge (SLC) plus \$ 1.75 for a total of \$ 5.25 , for all states except District of Columbia which had a lower SLC. The state regulators are free to provide additional support and the federal administration is committed to providing 50 cents of additional support for each dollar of state subsidy up to a cap.[24] The federal Linkup program provides a discount equal to the minimum of \$ 30 and 50% of the regular price. State regulators are free to provide Linkup support and there is no form of federal Linkup matching.

Estimates of the participation in Lifeline and Linkup are available at the state level. I employ a filing of National Consumer Law Center (2001) to the FCC to obtain an estimate of the ratio of participants to eligible consumers. This participation rate is cross checked with the FCC monitoring report (1999).

The HCPM program compares the state average costs of non rural ILECs to the national average in order to determine the subsidy funds available to a given state. For those states exceeding 135% of the national average, the ILEC is eligible to high cost model support. The subsidy at each wire center in that state will equal 76% of the difference between wire center cost per line and the national average. If the subsidy exceeds a cap of state available funds, it will be reduced proportionally in all wire centers. The states affected in the sample include AL, KY, ME, MS and WV.

The hold-harmless provision would initially keep constant the total amount of support for non rural ILECs excluded from the high cost model program. The FCC Thirteenth Report and Order (2000) set up a phase down schedule of this interim program. The states in the sample affected by hold-harmless provisions are AR, CO, KY, NM and SC, but they did not receive this form of subsidy after year 2000. In year 2000, the hold-harmless contribution to state s was

[24] The cap on federal lifeline subsidy per line was \$ 7 for year 2000. Given a basic federal subsidy of \$ 5.25, state regulators can anticipate additional federal funds for state subsidies below \$ 3.5.

fixed at a given level HHC_s, but the phase down schedule entailed that the contribution in a subsequent year t would be given by:

$$HHC_s(t) = \left(\sum_{z=1}^{Z_s} \sum_{j=1}^{N_{zs}} l_{jz} + l_s \right) \cdot \max \left(\frac{HHC_s}{\left[\sum_{z=1}^{Z_s} \sum_{j=1}^{N_{zs}} l_{jz} + l_s \right]} - t,\ 0 \right)$$

where l_{jz} and l_s denote respectively the number of residential lines of the regulated firm in local market jz and all other telephone lines in state s. The state s contains Z_s price zones with N_{zs} local markets in each price zone z. The term $-t$ implies that the hold-harmless support per line is reduced every year. I define T_s as the last year in which a state s receives a hold-harmless contribution and assume that state regulators do not induce demand variations big enough to alter this temporal threshold. The correction to marginal profit from a price increase $\partial p_z(m)$ is then:

$$\sum_{t=1}^{T_s} \frac{\partial HHC_s(t)}{\partial p_z(m)} = \sum_{t=1}^{T_s} -\frac{r_s}{(1+r_s)^t} \cdot t \cdot \frac{\partial l_{jzg}}{\partial p_z(m)}$$

where the term $r_s / (1+r_s)^t$ converts the temporal effect of the hold-harmless provision into a monthly perpetuity.

B Appendix: Mean Value Algorithm

I detail in this appendix the algorithm used to implement the contraction in (15). As presented in Section 5.1, the algorithm initially applies the iteration step in (15) to all 6854 observations and, as the number of iterations increase, it continues the application of the step in (15) only in those markets that have not reached a solution. If the step in (15) was applied repeatedly to all 6854 observations, the time for the computation would increase prohibitively as local markets with high telephone penetration require a high number of iterations. Less than 1% of the sample exceeds a telephone penetration level higher than 0.999, but it would force thousands of unnecesary iterations for the remaining 99% of the observations if this precaution is not taken.[25] I employ then the following procedure:

[25] For the available data, the typical demand specification in Section 6 and parameter values close to the truth, 700 iterations are required for convergence if $s_n \leq 0.95$. For $0.95 \leq s_n \leq 0.99$, this number climbs to 1750. For $0.99 < s_n$, this number exceeds 4500.

Mean Value (δ_n) algorithm

For a total number of N local markets, define an appropriate norm $\|.\|$over differences[26] $\delta_T^{it+1} - \delta_T^{it}$. Then,

Step 0: Set $T = N$, $\delta_T^1 = \widehat{\delta}$ for pre-existing estimate $\widehat{\delta}$, define number of iterations $it\_step = 100$ and choose tolerance level $tol = 1e^{-6}$.

Step 1: Apply step (15) for a number of iterations it_step.

Step 2: Check whether $\left\|\delta_T^{it\_step} - \delta_T^{it\_step-1}\right\| \leq tol$. If "*yes*" stop the procedure. If "*no*", proceed to step 3.

Step 3: Save the value $\delta_{T_{tol}}^{it\_step}$ for local markets $\delta_{T_{tol}}^{it\_step} \subseteq \delta_T^{it\_step}$ such that $\left\|\delta_{T_{tol}}^{it\_step} - \delta_{T_{tol}}^{it\_step-1}\right\| \leq tol$.

Step 4: Use $\delta_{T_{no}}^{it\_step} \subseteq \delta_T^{it\_step}$ such that $\left\|\delta_{T_{no}}^{it\_step} - \delta_{T_{no}}^{it\_step-1}\right\| > tol$ to set $\delta_T^1 = \delta_{T_{no}}^{it\_step}$ and $T = T_{no}$. Increase the number of iterations to $it\_step = it\_step + 50$. Revert to step 1.

There is also a time cost of selecting and saving observations that achieve their solution. I have chosen to increase the number of iterations by 50 after each stop and obtain satisfactory results. Computational procedures considered in Su and Judd (2008) and applied to BLP demand estimation by Dube et al. (2008) might also improve the computation of mean value.

C Appendix: Joint estimation of cost and welfare weights

I adjust the cost and welfare weight specifications to obtain an estimate of marginal cost at the zone level from the first order conditions in (9) and (10):

$$mc_{jz} = \gamma \cdot Cost_z + \omega_z + \omega_{jz} \tag{22}$$

$$\log(\lambda_z) = \phi \cdot Pol_z + \eta_z \tag{23}$$

[26] The norm $\|.\|$ is defined as the max $\left|\delta_t^{it+1} - \delta_t^{it}\right|$ across $t \in \{1, 2, ..., T\}$. The symbol δ_T^{it} denotes the it vector of $(T \times 1)$ mean values for T local markets.

where all unobserved shocks (ω_z, ω_{jz},η_z) are uncorrelated with cost and policy shifters. For each zone z, I assume a common expected marginal cost $E\left[mc_{jz} \mid \iota_s\right] = mc_z = \gamma \cdot Cost_z + \omega_z$ as in (22) and a common weight λ_z across the groups ($\lambda_{z1} = \lambda_{z2} = \lambda_z$) as in (23). This specification assumes a regulator with a relatively coarse knowledge of its jurisdiction, as there is no information of cost variation within a zone. It has the advantage of not requiring cost data as marginal cost is inferred from first order conditions and it also allows for zone level unobserved error ω_z on the regulator's expected marginal cost. I can then rewrite (9) and (10) as:

$$\frac{\lambda_z}{1+\mu_s} \cdot \partial CS_{zp} + \partial R_{zp} - mc_z \cdot \partial D_{zp} = 0 \tag{24}$$

$$\frac{\lambda_z}{1+\mu_s} \cdot \partial CS_{zd} + \partial R_{zd} - mc_z \cdot \partial D_{zd} = 0 \tag{25}$$

where the following abbreviations have been employed:

$$\partial D_{zp} = \sum_{j=1}^{N_{zs}} \sum_{g=1}^{2} \frac{\partial D_{jzg}}{\partial p_z(m)} \qquad \partial D_{zd} = \sum_{j=1}^{N_{zs}} \frac{\partial D_{jz2}}{\partial d_z(m)}$$

$$\partial R_{zp} = \sum_{j=1}^{N_{zs}} \sum_{g=1}^{2} D_{jzg} + \frac{\partial D_{jz1}}{\partial p_z(m)} \cdot \left(\widetilde{p}_{zg}(m) + \widetilde{p}_{zg}(c) \cdot r_s\right)$$

$$\partial R_{zd} = \sum_{j=1}^{N_{zs}} - D_{jz2} + \frac{\partial D_{jz2}}{\partial d_z(m)} \cdot \left(\widetilde{p}_{z2}(m) + \widetilde{p}_{z2}(c) \cdot r_s\right)$$

$$\partial CS_{zp} = \sum_{j=1}^{N_{zs}} \sum_{g=1}^{2} \frac{\partial CS_{jzg}(.)}{\partial p_z(m)} \qquad \partial CS_{zd} = \sum_{j=1}^{N_{zs}} \frac{\partial CS_{jz2}(.)}{\partial d_z(m)}$$

I can rearrange the conditions in (24) and (25) to solve for mc_z and $\lambda_z/\left(1+\mu_s\right)$. The subtraction of (24) times $\partial CS_{zd}/\partial CS_{zp}$ from (25) yields mc_z. Formally,

$$mc_z = \frac{\partial R_{zd} - \frac{\partial CS_{zd}}{\partial CS_{zp}} \cdot \partial R_{zp}}{\partial D_{zd} - \frac{\partial CS_{zd}}{\partial CS_{zp}} \cdot \partial D_{zp}} \tag{26}$$

Given mc_z, it is immediate to derive $\omega_z = mc_z - \gamma_z \cdot Cost_z$ and it is also possible to obtain $\lambda_z/(1+\mu_s)$ from the substitution of mc_z into (24). After some simplifications, I derive:

$$\frac{\lambda_z}{1+\mu_s} = \frac{\partial R_{zd} \cdot \partial D_{zp} - \partial R_{zp} \cdot \partial D_{zd}}{\partial CS_{zp} \cdot \partial D_{zd} - \partial CS_{zd} \cdot \partial D_{zp}} \tag{27}$$

It is possible to eliminate the Lagrangian multiplier μ_s by using differences of the expression in (27) across consumer groups in different zones, as presented in Section 5. Alternatively, it is possible to avoid the bias from the omission of μ_s by the inclusion of suitable state fixed effects in the equation for welfare weights. The index over the set of all welfare weights is now $v \in \{1, ..., V\}$ with $V = \sum_{s=1}^{S} Z_s$ (number of zones). For marginal cost observations, I use the index $q \in \{1, ..., Q\}$ where $Q = \sum_{s=1}^{S} Z_s$. The set of available welfare weights and costs are collected as $\{\lambda_1, ..., \lambda_V\}$ and $\{mc_1, ..., mc_Q\}$. I then take the following marginal cost and weight equations to the data:

$$mc_q = \gamma \cdot Cost_q + \omega_q \tag{28}$$

$$\log(\lambda_v) - \log(1+\mu_s) = \sum_{s=2}^{S} \phi_s \cdot 1(s)_v + \phi \cdot Pol\_S_v + \eta_v \tag{29}$$

where the observations for mc and λ are computed from (26) and (27). The motivation of the use state fixed effects is the same as in Section 5.

Empirical Results

The empirical results for the specification in this appendix are presented in Table 10. The policy controls Pol_v considered include the price zone averages of $Total\ hhs\ (k)$, $\%\ Rural$ and $\%\ Poor$ whereas I choose the price zone averages of $Total\ hhs(k)$, household $Density$, $\%\ Rural$ and $\%\ MSA$ for cost controls $Cost_p$.

The estimates of policy parameters ϕ include $Total\ hhs(k)$ (0.0002), $\%\ Rural$ (-0.003), and $\%\ Poor$ (-0.26) against the common wisdom of a bias in favor of poor and rural areas. Only the variable $\%\ Poor$ and the constant are significant. A Wald test, $W - test\ Weights$, on the estimated sum of squared weight differences $\chi_{\lambda*}$ cannot reject the hypothesis that there is no systematic difference in weights given a statistic value of 1.77 for a $\chi_2(1)$. The estimates for the parameters in ϕ that affect the general population in Table 6 and Table 10 are in line.

The lack of flexibility of the weights in the specification in this appendix does not affect these estimates.

The estimates for cost parameters γ reveal that less rural areas are assigned a higher cost given $Rural$ (-0.24) and % MSA (1.84). Only the constant and % MSA terms are significant in the cost regressions. The estimated marginal cost is too close to \$ 0 and far from the HCPM benchmark of \$ 23 to be realistic. I attribute the unnatural cost estimate to misspecification coming from the assignment of a single weight to each area rather than allowing a different weight λ_{z2} for the low income population. The current model assigns low costs rather than high consumer bias in favor of poor rural consumers to rationalize the prices in those regions. This illustrates the limitations in the use of optimality conditions for estimation with limited cost information.

D Appendix: Variance Covariance Matrix

The variance covariance matrix $\widehat{\Sigma}_\Theta$ of the estimated parameters $\hat{\Theta}_D \equiv (\widehat{\beta}, \widehat{\alpha})$ and $\hat{\Theta}_S \equiv (\widehat{\gamma}, \widehat{\phi})$ is obtained from the general GMM variance covariance formula:

$$\widehat{\Sigma}_\Theta = (1/N)(\Gamma^T \Omega \Gamma)^{-1} \Gamma^T \Omega \Psi \Omega \Gamma (\Gamma^T \Omega \Gamma)^{-1}$$

where Γ is the Jacobian of the derivatives of moment conditions with respect to parameters in Θ_D and Θ_S. The term $1/N$ comes from the asymptotic scaling term $\sqrt{N}$ applied to all the moments in f in Section 5. The expression in Ψ corresponds to the variance covariance of moments. Formally,

$$\Gamma = \begin{bmatrix} \partial f_W / \partial \Theta_D & 0 \\ \partial f_{Cost} / \partial \Theta_D & \partial f_{Cost} / \partial \Theta_s \\ \partial f_{Pol} / \partial \Theta_D & \partial f_{Pol} / \partial \Theta_s \end{bmatrix}$$

$$\Psi = \begin{bmatrix} \frac{1}{N}\sum_{s=1}^{S}\Phi_s^T\Phi_s & 0 & 0 \\ 0 & \frac{N}{Q}\cdot\sum_{q=1}^{Q}\left(\omega_q\cdot Cost_q\right)^T\left(\omega_q\cdot Cost_q\right) & 0 \\ 0 & 0 & \frac{N}{V}\sum_{v=1}^{V}\left(\eta_v\cdot Pol_v\right)^T\left(\eta_v\cdot Pol_v\right) \end{bmatrix}$$

The block diagonal structure of Ψ follows from the assumption of no correlation between demand, cost and policy moments. Formally, I assume that the following condition holds $E\left[Cost^T\cdot\omega\cdot\xi\cdot W\right] = E\left[Pol^T\cdot\eta\cdot\xi\cdot W\right] = E\left[Pol^T\cdot\eta\cdot\omega\cdot Cost\right] = 0$ (and the same zero covariance condition for the antisymmetric elements in Ψ).[27] The expression $\Phi_s = \sum_{n=1}^{N(s)}\xi_n\cdot W_n$ for n in state s allows for clustering of arbitrary form at the state level for the demand unobserved component ξ.

In Section 5.2, I introduced in equation (18) the ratios of welfare weights λ^* for different consumer groups in a state s. The set of available weight differences is $\left\{\lambda_1^*, ..., \lambda_{V-S}^*\right\}$, where S equals the number of states, as one weight in each state must be used as base to form the differences. The variance of a particular difference in weights $\widehat{\sigma}_{\lambda^*}^2$ can be obtained from $\widehat{\Sigma}_\Theta$ by a simple application of the delta method because weight differences are a function of Θ_D and Θ_S. If I define the Jacobian of a weight difference λ^* with respect to the parameters of the model as $\Gamma_{\lambda^*} = \partial\lambda^*/\partial\Theta$, it is possible to derive that:

$$\widehat{\sigma}_{\lambda^*}^2 = \Gamma_{\lambda^*}\cdot\widehat{\Sigma}_\Theta\cdot\Gamma_{\lambda^*}^T$$

The same method can be applied to any function of $\left\{\lambda_1^*, ..., \lambda_{V-S}^*\right\}$ to form suitable variances and *Chi-2* tests. I exploit this possibility to test the hypothesis that the sum of the squared weight differences is equal to zero. The test statistic is given by:

$$\chi_{\lambda^*} = \left(\lambda_1^*\right)^2 + ... + \left(\lambda_{V-S}^*\right)^2$$

If this test rejects $\chi_{\lambda^*} = 0$, it provides evidence of systematic bias across different consumers.

[27] A sufficient condition for this covariance structure to hold is the absence of correlation between unobserved shocks given exogenous variables, e. g., $E\left[\xi\cdot\omega|\ W, Cost\right] = 0$.

E Appendix: Analysis of Instrumental Variables

In this section, I present the analysis of the strength of the set of instruments employed in Section 5 and the endogeneity of monthly and connection prices. The statistics were obtained with the ivreg2 Stata module developed by Baum et al. (2007). Stock, Wright and Yogo (2002) provide a general guide into the weak instruments literature.

The results in column (a) of Table 11 correspond to the to the IV^* specification for *All households* in Table 3. It seems that the proposed set of instruments is strong for *Monthly_ 50* with high Shea's Partial R^2 (0.47) and F statistic (33.16), but it is not fully satisfactory for $Subsidy\_50$ with an F statistic below the threshold value of 10 accepted as a rule of thumb in the weak instruments literature from results in Staiger and Stock (1997). The use of cluster-robust standard errors blurs the meaning of this comparison as the standard test results are developed for the case of i.i.d. errors.[28] Given this uncertainty about the strength of the instruments, I perform tests robust to the presence of weak instruments for the joint significance of $Monthly\_50$ and $Subsidy\_50$. The Anderson-Rubin Wald test and Stock-Wright LM statistic reject the hypothesis of no joint significance of the coefficients on the monthly charges.

The column (b) in Table 11 considers an alternative specification with *Connection* and *Subsidy_ Connection* as additional endogenous variables. The robust endogeneity test for individual variables in Section 5 of Baum et al. (2007) rejects the hypothesis of exogenous *Monthly_ 50* and *Subsidy_ 50* given a value of the statistic (5.99). An analogous test of the joint endogeneity of all the price variables also rejects exogeneity (8.24). A test of endogeneity of $Connection$ and $Subsidy\_Connection$ given endogenous $Monthly\_50$ and *Subsidy_ 50* fails to reject exogeneity (5.42). I have thus no evidence in favor of endogenous connection charges. However, weak instruments can affect the power of the endogeneity test and the proposed set of instruments is weak for these new variables with partial R^2 values (0.076) and (0.084) and low F statistic val-

[28] Stock and Yogo (2001) develop a rigorous test for the presence of weak instruments but it also excludes the presence of clustering in the errors. The comparison of suitable Kleibergen-Paap statistics to critical values of Yogo and Stock is not easily interpretable.

ues. The robust Anderson-Rubin Wald test rejects again the hypothesis of no joint significance but the Stock-Wright LM statistic does not reject in this specification.

The bottom part of Table 11 reproduces the analysis for the poor population and it obtains analogous results with evidence in favor of the endogeneity of the monthly fee of low income households $Monthly\_50(sub)$ and strength of the instruments used for this variable. I do not repeat the analysis for the top part of the table and the reader is referred directly to Table 11.

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Table 1: Summary Statistics

	All Wire Centers		Wire Centers <100%	
N	7118		6854	
(a)	Mean	Sd	Mean	Sd
Tel Pen Total	0.971	0.030	0.970	0.030
Tel Pen Poor	0.923	0.063	0.920	0.063
Total hhs	9646	12140	9944	12268
% Black hhs	0.097	0.172	0.100	0.175
% Asian hhs	0.016	0.036	0.016	0.036
% Native hhs	0.008	0.033	0.008	0.033
% Other hhs	0.041	0.068	0.041	0.068
% Rural	0.397	0.408	0.391	0.407
% MSA	0.630	0.479	0.626	0.480
% Poor hhs	0.123	0.079	0.125	0.078
Median hh income (k)	43.664	17.246	42.998	16.588
(b)	Mean	Sd	Mean	Sd
% Dem-Leg	0.541	0.130	0.540	0.128
% Dem-PUC	0.347	0.271	0.348	27.325
Elected	0.168	0.374	0.174	0.379
Business/Residential Ratio	0.577	0.141	0.575	0.142
Competition in 1995	0.155	0.362	0.154	0.361
% CLEC lines in 1999	0.044	0.019	0.042	0.016
% CLEC res. lines in 1999	0.021	0.020	0.020	0.020
Monthly_0	11.176	2.315	11.167	2.307
Monthly_50	13.588	2.495	13.575	2.480
Monthly_100	15.815	2.747	15.781	2.717
Monthly_200	16.839	3.225	16.802	3.217
Monthly_0(sub)	3.203	2.048	3.218	2.048
Monthly_50(sub)	5.066	2.433	5.071	2.443
Monthly_100(sub)	7.277	3.077	7.257	3.081
Monthly_200(sub)	8.498	4.125	8.485	4.139
Connection	36.163	11.336	36.103	11.311
Connection (sub)	12.465	7.532	12.506	7.553
LCA hhs	228450	420021	230782	424999
(c)	Mean	Sd	Mean	Sd
Average cost per line	38.060	27.627	37.872	27.424

Note. In panel (b), variables from $\%\ Dem-Leg$ to $\%\ CLEC\ res.\ lines\ in$ 1999 are reported at the state level. The variables $\%CLEC\ res.lines\ in$ 1999 and $\%\ CLEC\ lines\ in$ 1999 miss observations for AZ, AR, ID, IA KS, KY, ME, NE, NV, NJ, NM, ND, OK, RI, SC, SD, WV.

Table 2: Summary of Key Notation

Symbol	Description
^{T}	Transpose of a vector or matrix
Model	
$z \in \{1, ..., Z_s\}$	Index over price zones in state s
$j \in \{1, ..., N_{zs}\}$	Index over local markets in zone z and state s
$g \in \{1, 2\}$	Index over income groups $g = 1$ and $g = 2$
P_{jz}	Probability of adoption of local telephone in market jz
x_{jz}	Exogenous demand conditions in market jz
M_{jz}	Number of households in market jz
$\widetilde{p}_{zg}(m), p_z(m)$	Net and Gross monthly prices for a group g in zone z
$\widetilde{p}_{zg}(c), p_z(c)$	Net and Gross connection fee for a group g in zone z
$d_z(m)$	Subsidy to monthly prices in zone z
$d_z(c)$	Subsidy to connection charge in zone z
$\alpha \equiv [\alpha_i(m), \alpha_i(c)]$	Marginal utility of change in $\widetilde{p}_{zi}(m)$ and $\widetilde{p}_{zi}(c)$ for a house i
ϵ_{ijz}	Idiosyncratic shock for house i in market jz
ξ_{jz}	Unobserved mean value in market jz
δ_{jz}	Total mean value in market jz
$\Theta_D \equiv [\alpha, \beta]$	Demand parameters include α and coefficients on x_{jz}
F_{jzg}	Joint distribution of income and ϵ for group g in market jz
D_{jzg}	Demand from group g in market jz
CS_{jzg}	Consumer surplus for group g in market jz
π_{jzg}	Profit from group g in market jz
λ_{zg}	Regulatory weight on group g in zone z
Pol_{zg}	Policy shifters on the weight of group g in zone z
η_{zg}	Unobserved policy shock on weight of group g in zone z
mc_{jz}	Marginal cost in market jz
K_{jz}	Fixed cost in market jz
$Cost_{jz}$	Vector of cost shifters in market jz
TC_{jz}	Total cost in market jz
w_{jz}	Unobserved cost shock in in market jz
$L(.)$	Lifeline state subsidy cost function
HCS_{jzg}	High Cost Subsidy originated by group g in market jz
$\Theta_s \equiv [\gamma, \phi]$	Supply parameters include coefficients on $Cost_{jz}$ and Pol_{zg}
r_s	Discount rate of the telephone operator in state s
B_s	Profit requirement for the regulator in state s
μ_s	Lagrange Multiplier for profit constraint in state s
W_s	Welfare function in state s
Estimation	
$n \in \{1, ..., N\}$	Index over all local markets observations in sample
$q \in \{1, ..., Q\}$	Index over all cost observations in sample
$v \in \{1, ..., V\}$	Index over all policy weight observations in sample
s_n	Actual telephone penetration in local market observation n
$1(s)_v$	Indicator for weight observation v belonging to state s
Pol_S_v	All variables in Pol_v excluding indicator $1(s)_v$
$I_{poor,v}$	Indicator for weight observation v belonging to $g = 2$

Table 3: Logit Demand Estimation (with homogeneous households)

All households (N=6854)				
	OLS		IV*	
	β	Sd(β)	β	Sd(β)
Constant	2.58	0.354***	3.001	0.404***
Monthly_50	-0.016	0.024	-0.077	0.025***
Subsidy_50	0.022	0.024	0.061	0.049
Connection	-0.008	0.007	-0.004	0.007
Subsidy_Connection	0.013	0.008	0.013	0.006**
% Black hhs	-1.470	0.153***	-1.515	0.171***
% Asian hhs	0.661	0.461	0.122	0.539
% Native hhs	-2.306	0.496***	-1.956	0.413***
% Other hhs	-2.448	0.749***	-2.806	0.704***
LCA hhs	0.078	0.068	0.097	0.074
% Rural	-0.358	0.052***	-0.369	0.054***
Median hh income	0.037	0.002***	0.036	0.002***
% MSA	0.248	0.051***	0.241	0.054***
Elasticity: *Monthly_50*	0.004	0.001***	0.016	0.001***
R2	0.662		0.652	
Hansen J-Stat			9.901(8)	

Poor households (N=6374)				
	OLS		IV*	
	β	Sd(β)	β	Sd(β)
Constant	2.225	0.273***	2.398	0.243***
Monthly_50 (sub)	-0.020	0.018	-0.058	0.023***
Connection (sub)	-0.007	0.007	-0.007	0.006
% Black hhs	-1.026	0.145***	-1.061	0.154***
% Asian hhs	2.504	0.618***	2.258	0.666***
% Native hhs	-1.928	0.495***	-1.668	0.426***
% Other hhs	-1.592	0.667**	-1.822	0.638***
LCA hhs	0.177	0.048***	0.194	0.044***
% Rural	-0.344	0.064***	-0.352	0.063***
Median hh income	0.018	0.003***	0.017	0.002***
% MSA	0.175	0.053***	0.173	0.054***
Elasticity: Monthly_50 (sub)	0.007	0.001***	0.024	0.001***
R2	0.375		0.365	
Hansen J-Stat			7.703(9)	

Note. The dependent variable is $\ln(s_n) - \ln(1 - s_n)$, where s_n is the telephone penetration for *All households* (upper panel) or *Poor households* (lower panel).
*,**,***; significant at 0.1, 0.05 and 0.01 levels.

Table 4: Logit Demand Estimation (with individual heterogeneity)

N	6854			
	(a)		(b)	
f	188.34		207.67	
	β	Sd(β)	β	Sd(β)
Constant	3.170	0.286***	3.189	0.335***
% Black hhs	-1.377	0.174***	-1.314	0.173***
% Asian hhs	0.595	0.526	0.459	0.513
% Native hhs	-1.925	0.362***	-2.293	0.532***
% Other hhs	-2.909	0.813***	-3.025	0.798***
LCA hhs	0.150	0.045***	0.149	0.074**
% Rural	-0.376	0.063***	-0.400	0.064***
% MSA	0.227	0.055***	0.213	0.053***
Median hh income	0.032	0.003***	0.032	0.004***
	α	Sd(α)	α	Sd(α)
$\widetilde{p}_{in}(m)$	-0.382	0.150**	-0.322	0.092***
$\widetilde{p}_{in}(c)$	-0.068	0.052	0.020	0.030
	$\varepsilon_{\widetilde{p}_{in}(m)}$	Sd($\varepsilon_{\widetilde{p}_{in}(m)}$)	$\varepsilon_{\widetilde{p}_{in}(m)}$	Sd($\varepsilon_{\widetilde{p}_{in}(m)}$)
All hhs	0.017	0.012*	0.016	0.007**
Low Income hhs	0.055	0.032*	0.054	0.027**
Normal Income hhs	0.002	0.001*	0.001	0.0006**
$Wald\_{elas}$	2.819(1)*		4.077 (1)**	

Note. GMM estimates with moments $E[(\delta(\alpha,.) - x\beta)'W]$. $Wald\_{elas}$ is a $\varkappa^2$ test for the difference between the elasticity of *Low Income hhs* and *Normal Income hhs.*
*,**,***; significant at 0.1, 0.05 and 0.01 levels.

Table 5: Marginal Cost Estimation with HCPM data

Q	7118					
	(a)		(b)		(c)	
	γ	Sd(γ)	γ	Sd(γ)	γ	Sd(γ)
Constant	74238	1092***	58089	1010***	57951	1094***
Res Lines	23.021	0.085***	21.810	0.073***	21.038	0.113***
Bus Lines	14.919	0.177***	14.671	0.148***	13.998	0.236***
Sa Lines	10.108	0.184***	10.923	0.150***	14.007	0.276***
Area			87.026	4.847***	87.483	4.824***
Area·Res Lines			0.013	0.001***	0.016	0.001***
Area·Bus Lines			0.041	0.003***	0.037	0.003***
Area·Sa Lines			-0.028	0.002***	-0.033	0.002***
Res Lines·Bus Lines					$10^{-5}\cdot4$	10^{-5}***
Res Lines·Sa Lines					$-10^{-5}\cdot4$	10^{-5}***
Bus Lines·Sa Lines					$-10^{-5}\cdot3$	10^{-5}***
R2	0.9829		0.9900		0.9903	
MC Res Lines						
Average			23.218		22.866	
Standard deviation			2.127		2.641	
Minimum			21.810		18.516	
Maximum			63.726		73.390	

Note. The dependent variable is TC_{HCPM}, the HCPM total cost in a wire center.
*,**,***; significant at 0.1, 0.05 and 0.01 levels.

Table 6: Estimation of Regulator's Welfare Weights

N,V	6854,312			
	Base Scenario			
	AC		*MC*	
	ϕ	Sd(ϕ)	ϕ	Sd(ϕ)
Constant	-0.0028	0.0194	0.0137	0.0138
Total hhs (k)	0.0012	0.0009	0.0002	0.0004
% Rural	0.0525	0.0258**	0.0028	0.0096
% Poor	-0.1576	0.1064	-0.1805	0.0855**
I_{Poor}	-0.0516	0.0574	0.0097	0.0301
Elected $\cdot I_{Poor}$	0.0563	0.0518	0.0201	0.0241
% Dem-Leg $\cdot I_{Poor}$	-0.1042	0.1204	-0.0074	0.0566
% Dem-PUC $\cdot I_{Poor}$	0.0399	0.0373	0.0178	0.0160
Total hhs (k)$\cdot I_{Poor}$	-0.0010	0.0017	-0.0005	0.0009
% Rural $\cdot I_{Poor}$	0.2882	0.1012***	0.0416	0.0303
% Poor$\cdot I_{Poor}$	1.2206	0.3851***	0.7895	0.2701***
R2	0.721		0.857	
W-test Weights	2.334(1)		1.5837 (1)	
	Federal I			
	AC		*MC*	
	ϕ	Sd(ϕ)	ϕ	Sd(ϕ)
Constant	-0.0302	0.0228	-0.0086	0.0159
Total hhs (k)	0.0003	0.0011	-0.0010	0.0005**
% Rural	0.0503	0.0371	-0.0117	0.0132
% Poor	0.8705	0.1237***	0.8792	0.0848***
I_{Poor}	-0.5273	0.0700***	-0.4873	0.0432***
Elected $\cdot I_{Poor}$	0.0684	0.0646	0.0166	0.0237
% Dem-Leg $\cdot I_{Poor}$	0.1261	0.1699	0.2931	0.0811***
% Dem-PUC $\cdot I_{Poor}$	0.0631	0.0502	0.0492	0.0218**
Total hhs (k)$\cdot I_{Poor}$	-0.0003	0.0023	0.0009	0.0010
% Rural$\cdot I_{Poor}$	0.3784	0.1458***	0.0639	0.0350*
% Poor$\cdot I_{Poor}$	-0.0170	0.4694	-0.5135	0.3211
R2	0.7768		0.9495	
W-test Weights	28.1269 (1) ***		10.2457(1)***	

Note. The dependent variable is $\ln(\lambda/1+\mu)$, the scaled welfare weight in (17). The *AC* and *MC* panels use respectively HCPM average cost and estimated marginal cost to recover weights in (17).
$^{*},^{**},^{***}$; significant at 0.1, 0.05 and 0.01 levels.

Table 7: Estimation of Regulator's Welfare Weights(contd.)

N,V	6854,312			
	Federal II			
	AC		*MC*	
	ϕ	Sd(ϕ)	ϕ	Sd(ϕ)
Constant	-0.0373	0.0403	-0.0097	0.0395
Total hhs (k)	-0.0005	0.0015	-0.0019	0.0015
% Rural	-0.0168	0.0482	-0.0809	0.0473
% Poor	0.7991	0.1530***	0.8217	0.1495***
I_{Poor}	-0.0893	0.0753	-0.0438	0.0571
Elected $\cdot I_{Poor}$	0.1943	0.0591***	0.1485	0.0371***
% Dem-Leg $\cdot I_{Poor}$	-0.7131	0.1427***	-0.6113	0.0990***
% Dem-PUC $\cdot I_{Poor}$	0.4222	0.0463***	0.4293	0.0341***
Total hhs (k)$\cdot I_{Poor}$	0.0017	0.0025	0.0028	0.0018
% Rural$\cdot I_{Poor}$	0.4494	0.1329***	0.1740	0.0533***
% Poor$\cdot I_{Poor}$	-0.2371	0.4701	-0.6481	0.3457*
R2	0.6616		0.6817	
W-test Weights	43.3011(1)***		17.1286(1)***	

Note. The dependent variable is $\ln(\lambda/1+\mu)$, the scaled welfare weight in (17). The *AC* and *MC* panels use respectively HCPM average cost and estimated marginal cost to recover weights in (17).
*,**,***; significant at 0.1, 0.05 and 0.01 levels.

Table 8: Cost Oriented Pricing Rules

(a) Average Cost Pricing		
	Total (m dollars)	Average (dollars)
ΔCS	-703.5905	-102,654
$\Delta\pi$	714.1037	104,188
ΔW	10.5132	1,534
$\Delta\widetilde{p}_{1n}(m)$		9.5393
$\Delta\widetilde{p}_{2n}(m)$		17.9658
ΔP_n		-0.0266
ΔP_n *(low income)*		-0.1058
(b) Marginal Cost Pricing		
	Total (m dollars)	Average (in dollars)
ΔCS	-700.4983	-102,203
$\Delta\pi$	716.740	104,572
ΔW	16.2473	2,370
$\Delta\widetilde{p}_{1n}(m)$		9.269
$\Delta\widetilde{p}_{2n}(m)$		17.851
ΔP_n		-0.0256
ΔP_n *(low income)*		-0.1036

Note. Results in Average column are measured in dollars except ΔP_n, change in penetration, which is measured in the $[0,1]$ scale.

Table 9: Optimal Pricing Rules

(a) Zone Regulator-I		
	Total (m dollars)	Average (dollars)
ΔCS	13.2873	1,939
$\Delta\pi$	.	.
ΔW	13.2873	1,939
$\Delta\widetilde{p}_{1n}(m)$		-3.9018
$\Delta\widetilde{p}_{2n}(m)$		17.512
ΔP_n		-0.0217
ΔP_n (*low income*)		-0.1255
(b) Zone Regulator-II		
	Total (m dollars)	Average (dollars)
ΔCS	-869.77	-126,899
$\Delta\pi$	883.58	128,914
ΔW	13.8052	2,014
$\Delta\widetilde{p}_{1n}(m)$		9.343
$\Delta\widetilde{p}_{2n}(m)$		17.872
ΔP_n		-0.0296
ΔP_n (*low income*)		-0.1278
(c) Multi Market Regulator -I		
	Total (m dollars)	Average (dollars)
ΔCS	15.8127	2,307
$\Delta\pi$	.	.
ΔW	15.8127	2,307
$\Delta\widetilde{p}_{1n}(m)$		-3.0151
$\Delta\widetilde{p}_{2n}(m)$		17.1840
ΔP_n		-0.0244
ΔP_n (*low income*)		-0.1023
(d) Multi Market Regulator -II		
	Total (m dollars)	Average (dollars)
ΔCS	-867.473	-126,563
$\Delta\pi$	883.58	128,914
ΔW	16.1089	2,350
$\Delta\widetilde{p}_{1n}(m)$		12.1750
$\Delta\widetilde{p}_{2n}(m)$		17.9558
ΔP_n		-0.0260
ΔP_n (*low income*)		-0.1040

Note. Results in Average column are measured in dollars except ΔP_n, change in penetration, which is measured in the $[0,1]$ scale.

Table 10: Estimation of Regulator's Welfare Weights and mc

N,Q,V	6854,156,156	
	ϕ	Sd(ϕ)
Constant	0.0109	0.0039***
Total hhs (k)	0.0002	0.0002
% Rural	-0.0033	0.0051
% Poor	-0.2580	0.1115**
	γ	Sd(γ)
Constant	1.7689	0.9491*
Total hhs (k)	-0.0458	0.0485
Density	-0.0004	0.0003
% Rural	-0.2428	1.2194
% MSA	1.8356	0.7404**
R2 Weights	0.7210	
R2 Cost Correction	0.0589	
W-test Weights	1.7713(1)	

Note. The dependent variable for the welfare weight equation is the scaled term $\ln(\lambda/1+\mu)$ in (27) and, for the marginal cost equation, the term mc in (26).
*,**,***; significant at 0.1, 0.05 and 0.01 levels.

Table 11: Instrument Analysis

All Households		
	(a)	(b)
Shea's Partial R2		
Monthly_ 50	0.471	0.2531
Subsidy_ 50	0.327	0.2401
Connection		0.0765
Subsidy_ Connection		0.0842
F-Stat	df = (10,43)	
Monthly_ 50	33.16***	24.96***
Subsidy_ 50	6.58***	5.42***
Connection		2.40**
Subsidy_ Connection		2.17**
WI Robust Significance Test	df = (10)	
Anderson-Rubin Wald test	33.99***	43.94***
Stock-Wright LM statistic	26.90***	23.58***
Endogeneity	df = (2)	df = (4), (11)
Ho: All Exogenous	5.99**	8.24*
Ho: Monthly Endogenous		5.42
Poor Households		
	(c)	(d)
Shea's Partial R2		
Monthly_ 50 (sub)	0.396	0.294
Connection (sub)		0.094
F-Stat	df = (10,43)	
Monthly_ 50 (sub)	13.07***	10.85***
Connection (sub)		1.63
WI Robust Significance Test	df = (10)	
Anderson-Rubin Wald test	41.03***	52.91***
Stock-Wright LM statistic	23.15**	23.83***
Endogeneity	df = (1)	df = (2, 11)
Ho: All Exogenous	4.582**	5.349*
Ho: Monthly Endogenous		4.758

Note. *,**,***; significant at 0.1, 0.05 and 0.01 levels.

Figure 1: Price Elasticity Distribution (Median Market)

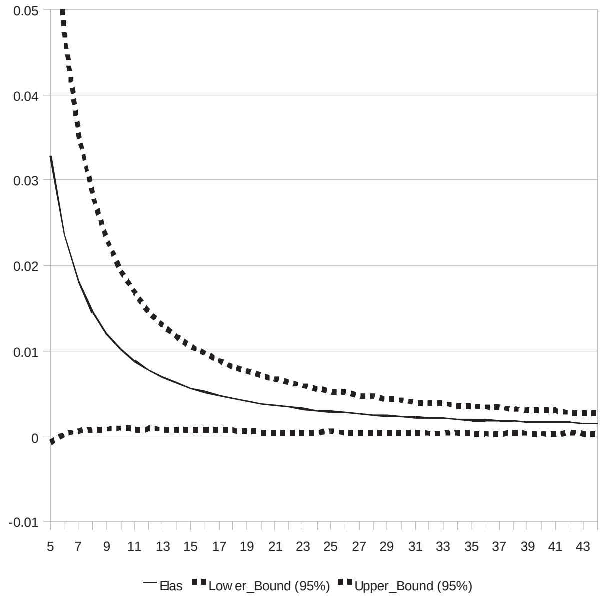


Figure 2: Price Elasticity Distribution (Low Penetration Market)

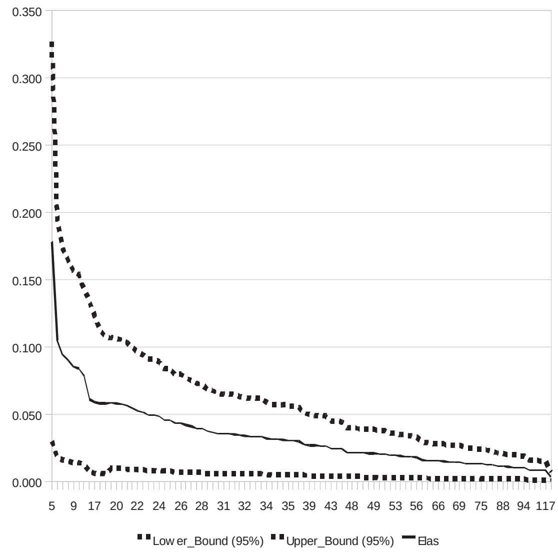


Figure 3: Base Case Differences in Consumer Weights (Logs)

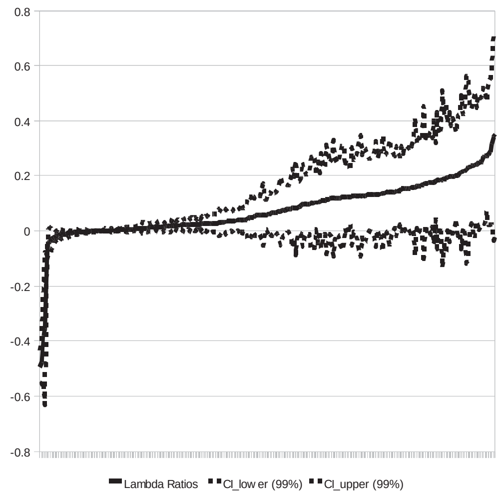


Figure 4: Federal I Differences in Consumer Weights (Logs)

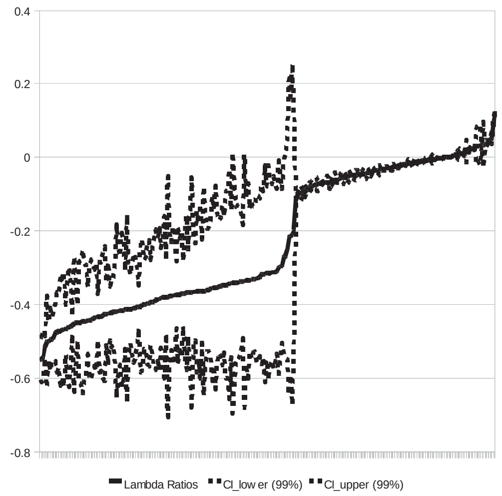
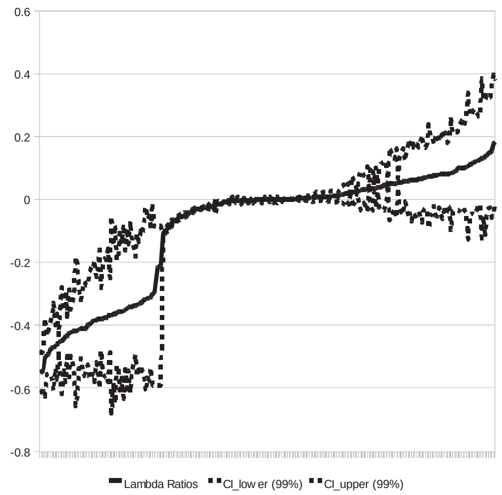


Figure 5: Federal II Differences in Consumer Weights (Logs)



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