Are all those Calling Plans Really Necessary? The Limited Gains From Complex Tariffs

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Abstract

This paper uses an equilibrium model of nonlinear pricing to determine the magnitude of foregone rents due to the implementation of simplified screening mechanisms. I then study the distribution of these foregone rents conditional on observable characteristics of a large sample of independent cellular telephone markets. Estimates reveal that the sample mean of foregone profits for not offering an additional tariff option amounts only to \$0.33 (1986 dollars) per subscriber although this amount declines to \$0.13 if cellular carriers already offer three tariff options. But these foregone profits only represent 4% and 0.6% of the profits attainable with a fully nonlinear tariff, respectively. The evidence presented in this paper suggests that, contrary to the current common practice, firms should only offer few tariff options if the product development costs of designing them are non–negligible. JEL: C39, D43, L96.

Keywords: Multipart Tariffs; Imperfect Screening; Foregone Welfare.

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1 Introduction

Over the past twenty–five years, the theory of nonlinear pricing has grown up to become a well established area of economics differentiated from other applications of asymmetric information and mechanism design models. The existence of heterogeneous consumers allows firms to increase their profits by engaging in price discrimination. According to the common interpretation of Arthur C. Pigou's (1932) *Second Degree Price Discrimination* paradigm, the types of individual consumers remain private information and the seller only knows the population distribution of types. In such an environment, a monopolist may maximize his expected profits through the design of a nonlinear tariff in an attempt to extract as much rents as possible from each consumer while minimizing agents' individual incentives to deviate from their optimal consumption.

The solution of this problem is well–known.[1] The optimal tariff is a nonlinear function of purchases that solves a complex variational problem defined by the preferences of consumers and the distribution of types. Under very general conditions, the optimal nonlinear tariff is a concave function leading to quantity discounts, *i.e.*, high valuation (large) customers are offered a lower price per unit than low valuation (small) consumers. By pricing large customers closer to marginal costs, nonlinear pricing enhances welfare while at the same time extracts sufficient rents from all consumers to cover fixed costs of production and/or distribution. Thus, nonlinear pricing is commonly used in industries where fixed or sunk costs are important but monitoring costs are low, such as in the case of electricity, water, gas, telecommunications, and cable television.

However, fully nonlinear tariffs are rarely implemented as such but rather through a menu of tariff options generally consisting of a fixed fee plus a use–dependent charge. The work of Gerald R. Faulhaber and John C. Panzar (1977) first showed that profits and welfare increase with the number of self–selecting two–part tariffs. Wilson (1993, §8.3) proved that the foregone rents of implementing a nonlinear tariff by means of an optimally designed piecewise linear approximation decrease rapidly with the number of tariff options offered. This result is proved in general for any well–behaved preferences and distribution of types leading to an optimal concave tariff.

But, how rapidly do incremental profits decline? This paper evaluates this critical magnitude in order to provide with some guidance on what should the optimal number of tariff options be in equilibrium. The optimal number of tariff options will be determined when the level of foregone incremental profits becomes comparable to reasonable costs of product development and commercialization. Do firms need to offer twenty or thirty tariff options to reach such low level? Or, will few tariff options do the job? The evidence presented in this paper favors the second alternative. Thus,

[1] Jean Tirole (1988, §3) and the first part of Robert B. Wilson's (1993) book present this solution in detail and include references to the abundant literature on this topic.

I call into question not only that theoretical models have ignored the costs of product development associated to any additional tariff offer, but also, and more importantly, the supposed profitability of current pricing strategies that offer dozens of tariff options to screen consumers.

Since the application of the Revelation Principle to solving pricing problems, theoretical models rarely have focused on anything different from fully nonlinear tariffs. Similarly, business practice leans towards crowding the market with numerous tariff options. For instance in Philadelphia, and among long distance carriers, it is possible to find just one –Opex Communications– that only offers one tariff option; Zone LD, Pioneer Telephone, and Verizon offer three options: while at the other end of the spectrum AT&T and Qwest offer five and seven tariff options, respectively. In the cellular market of Philadelphia Liberty Wireless and Sprint are among those who offer less options, five and seven, respectively while AT&T offer forty–four and Nextel sixty options between local and national plans. Are all those plans really necessary? Do firms benefit as much from such targeted screening of heterogeneous consumers? Is it possible that *product development costs* and design of tariff options could overcome the potential incremental profits of an additional option when the firm is already offering many choices?

This paper addresses these questions using data on pricing strategies of telephone carriers in the early U.S. cellular telephone industry. This is the first attempt to use data from a particular industry (instead of just numerical examples) to evaluate the actual foregone rents from offering only few tariff options. The evidence supports the hypothesis that small unobserved *product development costs* should prompt firms to offer few tariff options to screen consumers. Although on average, a firm in the sample that offers only a two–part tariff gives up \$1.48 per customer for not offering a second tariff option, this average foregone profits of price discrimination plunges to \$0.06 per customer for the same firm if it offers just three tariff options. Perhaps a more striking result, in particular for efficiency–conscious economists, is that these magnitudes represent, on average, a welfare loss of only 8.27% and 1.32%, respectively, relative to the welfare level attainable under a fully nonlinear tariff in the absence of screening costs.

Determinants of *product development costs* fall within the category of firm/market unobserved heterogeneity. This prevents an equilibrium analysis of the determinants of the number of tariff options. Whether firms have to engage in active market research to design the optimal tariff in each market that it operates is not observable to the econometrician and thus the costs that influence the pricing strategies are difficult to establish. Furthermore, since the theoretical literature on nonlinear pricing offers very little guidance on matters regarding the number of tariff options that firms "should" offer, I would have first to establish what will influence these *product development costs* if these cost indicators were available. Therefore, a potentially more fruitful

approach consists first to identify the magnitude of these costs and then describe how they vary with commonly available market characteristics.

The empirical analysis is conducted here in three stages. First, I use an equilibrium model of fully nonlinear pricing. The information available on the shape and position of the tariffs offered each quarter by each firm in each market allows me to recover the relevant structural elements driving the optimal pricing strategy.[2] They include the indexing parameter of the distribution of asymmetric information, marginal costs, and the size of the subset of active consumer types. This approach allows me to obtain price–independent indicators of the informational features of each market taking the pricing behavior of firms as optimal. The advantage of this approach is that it uses straightforward econometric methods and commonly available data –firms' tariff schedule– to summarize the relevant informational features of the market, in particular the distribution of types, with a few structural parameters that are later used to compute expected welfare magnitudes. The second stage of the empirical analysis addresses the estimation of the distribution of foregone rents due to imperfect screening. Once the distribution of consumer types and marginal costs of each firm–quarter observation are identified, the optimal, fully nonlinear tariff can be computed. In addition, I also compute the optimal multipart tariff that would best implement the fully nonlinear solution for an arbitrarily chosen number of tariff options.[3] I repeat this procedure for the different number of tariff options offered in the sample so that I can compute the welfare loss of not offering the fully nonlinear tariff and the foregone profits of not offering an additional optimal tariff option according to the pricing strategy actually implemented each quarter in every market. The estimate of the foregone incremental profits of not offering an additional tariff option provides, in this equilibrium framework, a lower bound estimate of the *product development costs*. Since these magnitudes are computed for every market–quarter combination in the sample, I therefore recover the empirical distribution of the efficiency loss indices and foregone earnings of each pricing strategy actually put in place. Finally, in the third stage of the empirical analysis I study the distribution of welfare loss and foregone earnings, conditional on observable characteristics of firms and markets. This is done taking advantage of the sample variation of pricing across markets and time.

1.1 Brief Literature Review

There are some papers that attempt to compare the relative performance of different pricing mechanisms. Alan J. Auerbach and Anthony J. Pellechio (1978) study the welfare effects of imposing

[2] This equilibrium approach assumes that the lower envelope of the menu of optional tariffs is optimal, but not that every single tariff option offered is optimally designed necessarily. This approach is less demanding on data requirements and in terms of the complexity of the econometric methods needed for the estimation, but most importantly, it avoid dealing with the optimal determination of the number of tariffs offered.

[3] These multipart tariffs are optimal in the sense that they are the best approximations to the fully nonlinear tariff within the set of a given number of self–selecting two–part tariff options.

full market coverage instead of allowing for an optimal exclusion policy when firms offer a single two–part tariff. Using simulations and *ad hoc* functional forms, Dionissis Dimopoulos (1981), Michael M. Murphy (1977), and Richard Schmalansee (1981) compare average cost pricing, two part tariffs, and nonlinear tariffs. Similarly, Wilson –in Section 6.3 of his book– addresses the case of multipart tariffs and computes several numerical examples to illustrate how rapidly few tariff options can approximate the results of a fully nonlinear tariff. In the present paper, I rely on a flexible model to estimate the money value of these foregone rents but instead of picking up arbitrary values for its parameters, I identify them through the profit maximizing equilibrium features summarized by the position and shape of the offered tariffs using data from the early U.S. cellular telephone industry. Working in this way I am able to set some bounds to the relevant magnitude of the *product development costs* that these firms faced in the early age of cellular communications.

Few recent papers have used actual data to either study the features of nonlinear pricing, or to evaluate the effects of alternative pricing strategies using reduced form or structural estimation methods. Among the first strand of empirical work, Meghan R. Busse (2000) analyzes how firms might use tariff features to collude in the presence of multimarket contact; Busse and Marc Rysman (2003) study how the shape of nonlinear tariffs varies with competition among firms; and Katja Seim and V. Brian Viard (2003) first address the effect that competition may have on variety of products as measured by the number of tariff options offered by competing firms. Among the second strand of literature, Phillip Leslie (2003) evaluates the increment in profits of introducing new quality categories in the pricing of a Broadway theater; Eugenio J. Miravete (2003) evaluates the expected welfare performance of alternative sequential screening mechanisms using optional tariffs and individual consumption of local telephone service in Kentucky; and Miravete and Lars–Hendrik Röller (2003) first use the shape of the offered tariffs by duopolists to evaluate how alternative pricing strategies would affect profits and welfare in a common agency framework.

1.2 Outline

Section 2 overviews the features of the early U.S. cellular telephone industry. Section 3 takes the shape and position of tariffs as an equilibrium feature of nonlinear pricing and describes how to recover the basic structural elements of a nonlinear pricing problem from the available data on tariff options actually offered by firms. The analysis of Section 4 serves the goal of identifying the foregone profits and consumer surplus in each market. Such an equilibrium approach allows me to identify these foregone rents under certain reasonable and flexible functional form specification and the basic equilibrium assumption that firms are maximizing profits when they offer a given number of tariff options. Section 4 also shows how do these foregone rents vary with market specific observable characteristics. Section 5 concludes.

2 The Early U.S. Cellular Telephone Industry

By mid 1980s, after debating for over a decade about standards, regulations, and licensing procedures, the Federal Communications Commission (FCC) granted permission to create 305 non–overlapping, duopolistic, cellular markets around U.S. standard metropolitan statistical areas (SMSAs). In 1981, the FCC set aside 50 MHz of spectrum in the 800 MHz band for cellular services. One of the two cellular channel blocks in each market –the B block or *wireline* license– was awarded to a local *wireline* carrier, while the A block –the *nonwireline* license– was initially awarded by comparative hearing to a carrier other than the local *wireline* incumbent.

For the first time, cellular technology used low powered transmitters that exhausted the allocated bandwidth within small cells. A single conversation with the older high powered transmitters of car phones used a channel within a radius of about 75 miles. The FCC required that the low powered transmitters of the new cellular technology used these channels within a maximum radius of 30 miles. Jerry A. Hausman (2002, §2.1) documents how the combination of cell splitting and sectorization increased capacity by a factor of 8 relative to pre–existing, non–cellular, car telephone technology. Only few affluent customers subscribed to the monopoly supplied car phone service, and thus, the expected return of the new technology was very high as the cellular technology promised to ease access to a much larger market. The substantial increase in communication capabilities and the moderate costs of investment prompted up to 579 contenders to apply for a single *nonwireline* license.[4]

Licenses were awarded in ten tiers, from more to less populated markets, beginning in 1983. In general the *wireline* licensee offered the service first and enjoyed a temporary monopoly position until the *nonwireline* carrier entered the market, normally within six months of being awarded the license as required by the FCC. However, the administrative review process to award licenses among hundreds of contenders only based on technical issues and investment commitments proved to be far more costly than expected.[5] After awarding the first thirty SMSA licenses by means of this expensive and time consuming *beauty contest*, and while the application review of the second tier of thirty markets was on its way, rules were adopted to award the remaining *nonwireline* licenses through lotteries. Court appeals against the administrative award of the *nonwireline* licenses in the earlier tiers, and legal, technical, or managerial difficulties to start operating the lottery–awarded licenses in subsequent tiers led to a situation of temporary monopoly in many local cellular markets.

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[4] The large number of applicants is partly explained by the low cost of completing the paperwork to enter the lottery –between $250 and $5,000–, compared to a very high expected immediate return since there were no restrictions to resale the *nonwireline* license other than not selling it to the operator of the *wireline* license.

[5] The FCC itself did not obtain any revenue from awarding the licenses. Thomas W. Hazlett and William B. Michaels (1993) study the economic consequences of this inefficient license awarding mechanism. See a further description of this market in Busse (2000, §2.1) as well as the account of the entry policy and regulation of these markets by William B. Shew (1994). Michael M. Murray (2002) offers a detailed review of the early development of this industry.

This is exactly the data used in the present study. I use detailed tariff information for about 70 *wireline* license holders who enjoyed a monopoly position in one of these SMSAs between 1984 and 1988. I focus on the monopoly period to avoid any strategic arguments that may arise when firms design their tariffs in competition with each other.[6] The quarterly data include the number of tariff plans, their monthly subscription fee, and rate per minute during peak hours (a common 11 to 13 hour band at that time). In addition, tariff data are complemented with market specific demand and cost information as well as an ownership indicator for each firm.

⟹ INSERT Table 1: Descriptive Statistics and Definitions ⟸

Table 1 defines all variables used in this paper and presents their sample distribution.[7] Firms design their nonlinear tariffs and the number of tariff options to be offered conditional on the relevant available information of each market. As mentioned before, I will not assume any particular effect of these variables on the magnitude of the foregone rents or the number of tariff options offered. Their inclusion in the econometric analysis accounts for market heterogeneity that is observable not only to the econometrician, but also to firms when they decide on their pricing strategies.

Demand might be higher or lower –and perhaps even more importantly– more or less dispersed depending on the size of the market (POPULATION, BUSINESS, GROWTH); the income per capita of its customers (INCOME, POVERTY); other market characteristics such as average commuting time (COMMUTE); and the distribution of other individual characteristics such as the age of the population or its average level of education (POP–AGE, EDUCATION). Data also include a time trend and the age of the market (TIME, MKT–AGE). These variables may summarize the dynamic effects of consumers' learning about the quality of the service –experience good component– or firms' learning related to the provision of the service, knowledge of the technology or managerial know how. Although learning might also be endogenously induced by the pricing practices of the firms, these time related indicators will only capture the exogenous elements of those dynamic effects.

The percentage of subscribers (COVERAGE) represents a direct indicator of the magnitude of demand at the actual tariffs offered by the temporary monopolists. This variable may also capture the existence of potential network effects. The consumption externality may appear because as coverage increases, there is an increasing number of potential parties to whom communication can be established bypassing the fixed local loop, and therefore avoiding interconnection charges.

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[6] Miravete and Röller (2003) use this same data set to estimate an equilibrium model of nonlinear pricing competition. However, they ignore the actual implementation of the tariffs through multipart tariff options to avoid having to define equilibrium strategies in a rather complicated strategy space. Such problems do not arise in the present monopoly environment.

[7] The bottom of Table 1 includes estimated magnitudes obtained according to the model described in Sections 3 and 4. I will comment those variables after having described such model.

Other available variables that might condition foregone rents and pricing practices are the scale of the firm and the level of marginal costs (TCELLS, ESTCOST). The marginal cost indicator is estimated by equating it to the marginal tariff paid by the highest consumer type, *i.e.*, imposing an equilibrium condition common to nonlinear pricing models. I will further discuss this identification issue in the next section. As for the scale of firms, I use the available number of operative antenna sites since the number of subscribers is not generally available. This approach is justified because as it is well documented –see Murray (2002) for instance–, at this early stage of development of the industry, the number of subscribers were effectively constrained by the capacity of cellular carriers.[8]

The entry of the second firm on the market was an exogenous event that depended on the diligence of the FCC to award licenses in a new tier of markets. But once these licenses were awarded, *nonwireline* carriers had the obligation to be up and running within six months. Ingo Vogelsang and Bridger Mitchell (1997, p.207) indicate that in order to ease this process, the FCC required the *wireline* company to offer unrestricted resale of its service until the *nonwireline* company was fully operational in order to foster competition and use of the cellular service. Once the *nonwireline* license was awarded, the incumbent in that particular market knew with certainty when will it face competition. This might perhaps prompt the incumbent to modify its pricing strategy in order to increase its customer base before facing effective competition. Indicator NEAREND identifies those observations that fall within the last six months of monopoly regime in each market.

I also include one additional indicator to condition foregone rents and pricing behavior of firms on the regulatory framework where they operate. Pricing regulation was not homogeneous across SMSAs as it was a competence of state regulatory commissions. About half of the sample falls within the category of markets where state regulators had to review and approve any tariff increase of the *wireline* carrier. Shew (1994, §3) provides evidence that supports the hypothesis that these firms, confronting the uncertainty of the behavior of the new cellular market and fearing future regulatory opposition to tariff increases, had very expensive tariff options approved at the startup of their license. Controlling for this variable will allow me to identify whether the existence of a regulatory review had any other effect on the magnitude of foregone rents or pricing strategies.

⟹ INSERT Table 2: Empirical Distribution of Number of Tari Plans ⟸

Finally, data also include indicators of the largest shareholder of each carrier, as well as the number of tariff plans offered each quarter by these firms in different markets. The firm indicators capture whether pricing strategies respond mostly to business group effects, perhaps through a centralized office that designs pricing strategies for very heterogeneous markets. This is a reasonable argument when product development and plan design are costly, when firms are quite uncertain

[8] Miravete and Röller (2003, §2) and Phillip M. Parker and Röller (1997, §4) report that one antenna could serve between 1,100 and 1,300 subscribers for the average use of cellular telephony at that time.

about the behavior of the market as in this early stage, or when they serve geographically close markets.[9]

3 An Equilibrium Model of Nonlinear Pricing

This section discusses how to use the position and shape of the offered tariffs to identify the basic elements of a price discrimination model, which will allow me to estimate the foregone incremental rents of not offering an additional optimal tariff option in Section 4 of the paper. In an equilibrium framework where the offering of a tariff option generates a fixed cost of product development and design, the estimated foregone profits of not offering an additional option provide with a valid lower bound estimate of the magnitude of the *product development costs*.

3.1 Tariff Shape and the Distribution of Consumer Types

Until very recently empirical work failed to recognize that the shape of tariffs of profit maximizing firms that engage in nonlinear price discrimination offers several sources of identification of relevant magnitudes for policy analysis. The optimal, single dimensional, nonlinear pricing strategy always implies *efficiency at the top*, *i.e.*, that the highest consumer type pays a marginal tariff equal to the marginal cost of production of that last unit. The monopolist's attempt to maximize revenues leads to positive markups for consumer types other than the highest. In such an attempt, the monopolist has to balance the extraction of informational rents with providing consumers with the right incentives for them not to imitate nearby consumer types. Thus, the optimal markup for each consumption level –and therefore the shape of the nonlinear tariff– depends critically on the actual distribution of consumer types. Indeed, for any demand specification, there is a bijective correspondence between the distribution of consumer types and the shape of the tariff. Thus, the marginal tariff for the highest potential consumption identifies the marginal cost, the shape of the tariff identifies the distribution of consumer types (provided some specification of demand), and the intercept of the tariff identifies the reservation utility of the marginal consumer, *i.e.*, the consumer that is indifferent between participating in the market or not.

3.1.1 A General Model of Nonlinear Pricing

To illustrate this argument I briefly describe the elements of a general model of nonlinear pricing:

[9] Busse (2000 §5) documents some of these practices in the cellular industry. In general, I tried to control by market fixed effects at the estimation stage, but there was not sufficient time variation for most regressors of each individual firm, and therefore such estimates turned out to be unfeasible beyond the identification of the intercept. I thus focus on the pool estimation controlling for company effects.

1. *Demand:* Consumers have a utility function $U(x, \theta)$ which is at least twice continuously differentiable, increasing and concave in x, increasing in θ, and strictly concave in (x, θ). Assuming away income effects, the corresponding demand $x(p, \theta)$ is defined by the budget constrained utility maximization condition $\partial U(x, \theta)/\partial x = p$. The demand function is decreasing in p, and because of the strict concavity of $U(\cdot)$ in (x, θ), it is such that $x_\theta(p, \theta) > 0$, *i.e.*, the well known single–crossing property (*SCP*) that ensures that demand of different consumers types can be ordered with respect to the type dimension.

2. *Costs:* I assume a constant returns technology. This is an accurate assumption for telecommunications industry, where fixed costs are quite more important than variable costs.

3. *Distribution of Types:* Preference parameter θ has a continuously differentiable probability density function $f(\theta)$ defined on a compact support $[\underline{\theta}, \overline{\theta}]$, and such that the corresponding cumulative distribution function is absolutely continuous. Together with *SCP*, the basic requirement to obtain a well behaved, monotone increasing, concave, nonlinear tariff solution is that the hazard rate of the distribution is increasing (*IHR*), *i.e.*, $h'(\theta) > 0$, where $h(\theta) = f(\theta)/[1 - F(\theta)]$.

4. *Nonlinear Tariff Solution:* The monopolist maximizes its expected profits subject to two constraints: that consumers choose optimally the level of consumption and the associated payment, and that consumers would only participate in the market if it is in their own interest to do so, *i.e.*, $\forall \theta > \theta^\circ$ where $\mathcal{U}(\theta^\circ) = \underline{\mathcal{U}} \geq 0$. The first is the incentive compatibility (*IC*) or truth–telling condition, and the second is known as the individual rationality (*IR*) constraint. This constrained maximization program can be written in a concise manner as the following optimal control problem:

$$\max_{T(\theta), \mathcal{U}(\theta)} \int_{\theta^\circ}^{\overline{\theta}} \{T[x(\theta)] - cx(\theta)\} \, dF(\theta), \tag{1a}$$

$$\text{s.t.} \quad \mathcal{U}(\theta) - \mathcal{U}(\theta^\circ) = U[x(\theta), \theta] - T[x(\theta)], \tag{1b}$$

$$\theta \in \arg\max_{\theta'} U[x(\theta'), \theta] - T[x(\theta')], \tag{1c}$$

$$\mathcal{U}(\theta^\circ) = \underline{\mathcal{U}} \geq 0. \tag{1d}$$

The optimality condition that solves this problem is:

$$T'[x(\theta)] = c + \frac{1 - F(\theta)}{f(\theta)} \cdot \frac{\partial^2 U[x(\theta), \theta]}{\partial x \partial \theta}. \tag{2a}$$

This condition indicates that the optimal price distortion over marginal cost is a function of the distribution of consumer types. Thus, the highest consumer type $\overline{\theta}$ pays a marginal tariff

equal to the marginal cost of production as the virtual utility component of the *r.h.s.* of equation ($2a$) vanishes. The reduction of markups for large customers is the source of efficiency gains of nonlinear pricing over standard linear pricing. Equation ($2a$) also shows that the distribution of types conditions the shape of the optimal tariff. Indeed, there is a one–to–one relationship between them for any given specification of demand, which in turn determines $\partial^2 U(x,\theta)/\partial x \partial \theta$. The above differential equation together with the initial condition ($1d$) defines the optimal tariff as:

$$T[x(\theta)] = \underline{\mathcal{U}} + U(x(\theta),\theta) - \mathcal{U}(\theta). \tag{2b}$$

3.1.2 An Operationally Feasible Formulation

In order to take advantage of the features of the data described in Section 2, I will make some functional form assumptions in order to implement the above theoretical framework in an operationally feasible manner. In the following paragraphs, I will emphasize some data and identification issues that justify these functional form assumptions.

1. *Demand:* I assume a quadratic utility function:

$$U(x,\theta) = \theta x - \frac{b}{2}x^2, \tag{3a}$$

that leads to the following linear demand function specification:

$$x(p,\theta) = \frac{\theta - p}{b}. \tag{3b}$$

A linear demand may appear very restrictive but it is justified here for two reasons. First and foremost, the data does not include individual purchasing decisions, and thus any functional form assumption for demand is necessarily an arbitrary choice. Second, the linear specification of demand allows me to write the solution of the pricing problem as a quadratic function of cellular telephone use, thus simplifying the econometric analysis needed to recover the structural parameters. The linear demand still fulfills *SCP* but the magnitude of the estimates obtained below could perhaps be made more accurate if individual data were available to select the specification of demand that better capture the behavior of consumers.

2. *Costs:* Marginal costs are constant. I do not impose symmetry of costs across firms and markets, and thus I allow for firm specific constant marginal costs c.

3. *Distribution of Types:* Consumer types are distributed according to a Burr type XII distribution of the form:[10]

$$\theta \sim F(\theta) = 1 - \left[1 - \frac{\theta - \underline{\theta}}{\overline{\theta} - \underline{\theta}}\right]^{1/\lambda}, \qquad \theta \in \Theta = [\underline{\theta}, \overline{\theta}]. \tag{4}$$

This distribution allows for a closed form solution of the optimal nonlinear tariff (together with the assumption of linear demand) while at the same time it facilitates an intuitive interpretation to the indexing parameter λ, which is inversely related to the hazard rate of the distribution of the types, and represents the ratio of high–to–low valuation customers. If $\lambda = 1$ this distribution coincides with the uniform, and thus, a larger (smaller) value of λ represents cases where there is a larger (smaller) proportion of high to low valuation customers. The Burr type XII distribution makes possible to implement the idea that nonlinear tariffs with different degrees of concavity identify the distribution of consumer types through the estimation of a single parameter λ. This intuition is illustrated in Figure 1, where I show some Burr type XII for few values of λ, and the corresponding solutions for the optimal nonlinear tariff considering the linear demand specification ($3b$). Different draws of λ will generate different nonlinear tariffs as shown in Figure 2. The role of the approximation methods discussed below is to identify the value of λ that generates the nonlinear tariff that best approximates the lower envelope of the actual tariff offered.

$\Longrightarrow$ INSERT Figures 1 and 2: Distributions and Tari Solutions $\Longleftarrow$

4. *Nonlinear Tariff Solution:* The optimality condition ($2a$) is easily rewritten in terms of these functional form assumptions as follows:

$$\theta - bx(\theta) = c + \lambda(\overline{\theta} - \theta). \tag{5a}$$

Observe that λ is directly related to the inverse of the hazard rate of the distribution of θ, and therefore directly related to the markup charged to different consumer types. The counterpart to the general tariff solution ($2b$) is:[11]

$$T[x(\theta)] = \underline{\mathcal{U}} + \left[\frac{c + \lambda\overline{\theta}}{(1+\lambda)}\right] x(\theta) - \left[\frac{b\lambda}{2(1+\lambda)}\right] x^2(\theta). \tag{5b}$$

[10] This distribution belongs to the family of beta distributions, and it fulfills the *IHR* property as long as $\lambda \geq 0$. For further results and properties of the Burr type XII distribution see Norman L. Johnson, Samual Kotz, and N. Balakrishnan (1994, §12.4.5).

[11] The model also provides the optimal solution for $x(\theta)$, which is equal to $[(1+\lambda)\theta - c - \lambda\overline{\theta}]/b$. However, I will not make use of this element of the model –except to identify the cutoff type θ°– because data on individual consumption are not available.

3.2 Approximation to a Nonlinear Tariff Function

Data include tariff options offered each quarter by *wireline* firms. These tariff options consist of two–part tariffs with a fixed monthly fee and a fixed rate per minute. It is a well known result that as the number of tariffs goes to infinity, the optimal nonlinear tariff is the lower envelope of these self–selecting two–part tariffs. The empirical strategy is therefore to approximate the lower envelope of the offered tariffs with the concave quadratic polynomial that best approximates it. Thus, the quadratic approximation to the actual tariff has the same analytical structure than the optimal tariff prediction ($5b$):

$$T(x) = \alpha + \beta x + \frac{\gamma}{2}x^2, \tag{6}$$

Parameters α, β, and γ are chosen to minimize the vertical distance between the quadratic polynomial (6) and the lower envelope of the tariffs offered each quarter by each firm. I fit this quadratic tariff to the lower envelope function on a grid of monthly telephone use defined on the unit interval, $x \in [0, 1]$, where the maximum consumption $x = 1$ corresponds to a 500 minutes of airtime communication per month.[12]

I perform two approximations using the least squares criteria. The first column of Table 3 reports the mean and standard deviation of the parameters that minimize the square of the errors of the vertical distance between (6) and the lower envelope of the tariff options for each firm in each quarter of the sample. In this case, the approximation to the nonlinear tariff function is made over a grid of 500 nodes uniformly distributed between 0 and 1 (that is, one corresponding to each minute of airtime usage). The second column of Table 3 reports another approximation, this time using 500 Chebychev nodes. Although there are little differences between the sample distributions of these two approximation procedures, I will base all the subsequent analysis in the latter approximation since the use of Chebychev nodes usually improves the accuracy at the boundaries of the approximation domain. This might actually be important in the present case because the lower bound determines the participation decision of consumers –the cutoff type θ°– and the upper bound determines the marginal cost c.[13]

$\Longrightarrow$ INSERT Table 3: Distribution of Tari Parameters $\Longleftarrow$

The quadratic polynomial (6) also proves very useful because recovering the structural parameters reduces to simple transformations of the estimated parameters of the functional approx-

[12] I have tried several other limits, but contemporaneous industry reports indicate that the average cellular usage was around 200 minutes a month. See the industry reports of the Cellular Telecommunications and Internet Association.

[13] In order to improve the accuracy of the estimated distribution of types, which is assumed to be time–invariant, the structural parameters of each market are those of the latest quarter among those with the largest number of tariff options offered. On the superior performance of Chebychev nodes see the extensive discussion in chapters 6 and 7 of Ralston and Rabinowitz (1978).

imation. Thus, equating coefficients of (6) with those of (5b), it is straightforward to show that the indexing parameter of the distribution of types is:

$$\lambda = \frac{-\gamma}{b + \gamma}. \tag{7}$$

Therefore, for any estimate of the slope of the linear demand, the degree of concavity of the polynomial –directly related to γ– uniquely determines the indexing parameter of the distribution λ.[14] Differentiating (6) and evaluating it at the maximum consumption, $x = 1$, the marginal cost is given by:

$$c = \beta + \gamma. \tag{8}$$

Next, equating the coefficients of x in (5b) and (6) and substituting (7) and (8) identifies the highest type as:

$$\overline{\theta} = b + c. \tag{9}$$

And finally, by making $\mathcal{U}(\theta^\circ) = \underline{\mathcal{U}}$ whenever $x(\theta^\circ) = 0$ we obtain:[15]

$$\theta^\circ = \beta. \tag{10}$$

Table 3 presents the sample distributions of these structural parameters. These are the results of computing the above transformations over the parameters α, β, and γ of 402 nonlinear tariff function approximations. These structural parameters define the fundamentals of each pricing problem solved by firms each quarter, and are the basis of the estimated foregone earnings of offering only a limited number of tariff options. The next subsection details how to compute these foregone earnings.

4 The Foregone Gains From Simplicity

In this section I study how to compute a menu of n–part tariff options where n is exogenously determined.[16] After characterizing these options in general, I will detail how to compute them for the specific case of linear demand and Burr type XII distribution presented in Section 3.

An n–part tariff consists of a fixed fee schedule A plus block–declining price schedule p with $n - 1$ segments such as $A_k < A_{k+1}$ and $p_k > p_{k+1}$, *i.e.*, the more expensive the fixed fee is, the

[14] The estimate of b used here corresponds to the system estimation reported in Section 4.2 of Miravete and Röller (2003) under the assumption of independence of the competing cellular services. The system estimation makes use of 22 observations where the market share information of the competing firms in 8 markets is available. The estimate of b is 5.2979 and its t–statistic is 54.39.

[15] This result is straightforward after making $x(\theta^\circ) = 0$ in the optimal consumption solution, *i.e.*, $[(1 + \lambda)\theta^\circ - c - \lambda\overline{\theta}]/b = 0$, and then comparing the solution with the coefficient on $x(\theta)$ in equation (5b). Notice in Table 3 that on average $\theta^\circ > c$ and thus some consumers are always excluded at the bottom, which is in accordance with the low penetration rate of cellular service at this early stage of the industry.

[16] The direct precedent of the material covered in this section is Wilson (1993, §6.4).

lower the corresponding rate per minute becomes. Thus, payments according to tariff option k are given by $T_k = A_k + p_k x$. The multipart tariff problem is also characterized by a couple of boundary conditions given by the behavior at θ° and $\overline{\theta}$, *i.e.*, the cutoff and highest consumer type, respectively. Thus, $(1d)$ and $(3b)$ lead to $p_0 = \theta_0 = \theta^\circ$ and $A_0 = \underline{\mathcal{U}}$, which represent the option of not purchasing at all. Similarly, at the other end $\theta_n = \overline{\theta}$. Furthermore, consumers of type θ choose the tariff option k if $\theta_k < \theta < \theta_{k+1}$.

The multipart tariff solution for a monopolist that wants to offer an n–part tariff given by $\{A_k, p_k\}$, $k = 1, \ldots, n-1$, is to find the optimal sequence of marginal tariffs $p_0 < p_1 < \ldots < p_{n-1}$ and switch types $\theta_0 < \theta_1 < \ldots < \theta_{n-1}$ that maximizes the expected profits given the demand behaviour, the distribution of types, and the restricted tariff strategy represented by the number of n–part tariffs offered. The profit contribution of consumers of type θ from purchasing tariff k is:

$$\Pi_k = A_k[F(\theta_{k+1}) - F(\theta_k)] + (p_k - c) \int_{\theta_k}^{\theta_{k+1}} x(p_k, \theta) dF(\theta), \tag{11a}$$

so that after aggregating across consumer types we obtain that the overall expected profits are:

$$\Pi = \sum_{k=1}^{n-1} \int_{\theta_k}^{\theta_{k+1}} [A_k + (p_k - c) x(p_k, \theta)] \, dF(\theta). \tag{11b}$$

The consumer payoff of subscribing to tariff option k is:

$$CS_k(\theta) = \int_{p_k}^{\infty} x(p, \theta) dp - A_k, \tag{12a}$$

and thus, the total expected consumer surplus becomes:

$$CS = \sum_{k=1}^{n-1} \int_{\theta_k}^{\theta_{k+1}} \left[\int_{p_k}^{\infty} x(p, \theta) dp - A_k \right] dF(\theta). \tag{12b}$$

In the absence of income effects, equation $(12a)$ also determines the incremental fixed fee that extracts all the informational rent of the switching consumer type who is indifferent between subscribing to tariff plan k and $k-1$:

$$A_k - A_{k-1} = \int_{p_k}^{p_{k-1}} x(p, \theta_k) dp, \tag{13a}$$

and thus, the fixed fee of tariff option k is found recursively as:

$$A_k = A_0 + \sum_{j \leq k} \int_{p_j}^{p_{j-1}} x(p, \theta_j) dp. \tag{13b}$$

Therefore, combining (11b) and (13b), the objective function of the monopolist becomes:

$$\Pi = \sum_{k=1}^{n-1} \left\{ \int_{\theta_k}^{\theta_{k+1}} (p_k - c) x(p_k, \theta) dF(\theta) + [1 - F(\theta_k)] \int_{p_k}^{p_{k+1}} x(p, \theta_k) dp \right\}. \tag{14}$$

The optimal two–part tariff option k is found by maximizing this expression with respect to $\{p_k, \theta_k\}$. After integrating by parts, the optimality conditions can be written as:

$$\frac{\partial \Pi}{\partial p_k} = \int_{\theta_k}^{\theta_{k+1}} \left[(p_k - c) \frac{\partial x(p_k, \theta)}{\partial p_k} + \frac{1 - F(\theta)}{f(\theta)} \frac{\partial x(p_k, \theta)}{\partial \theta} \right] dF(\theta) = 0, \tag{15a}$$

$$\frac{\partial \Pi}{\partial \theta_k} = \int_{p_k}^{p_{k-1}} \left[(p - c) \frac{\partial x(p, \theta_k)}{\partial p_k} + \frac{1 - F(\theta_k)}{f(\theta_k)} \frac{\partial x(p, \theta_k)}{\partial \theta_k} \right] dp = 0. \tag{15b}$$

Once the optimal p_k and θ_k are found, equation (13b) provides us with the solution for the optimal fixed fee A_k. Notice that in the limit, as the number of parts goes to infinity, the increments $\theta_{k+1} - \theta_k$ and $p_k - p_{k-1}$ become negligible and any of these two conditions become identical to (2a), the optimality condition of a fully nonlinear tariff. In addition, the boundary conditions $\theta_n = \overline{\theta}$, $p_0 = \theta_1$, and $A_0 = \underline{\mathcal{U}} = \alpha$, the latter after equating the intercepts of (5b) and (6), need to be fulfilled.

4.2.1 The Particular Solution

As Table 2 shows, firms in the sample offer a maximum of 6 tariff options. Once I recover the structural parameters $\{c, \lambda, \theta^\circ, \overline{\theta}\}$ for each firm using the particular model of Section 3.1.2, it is possible to compute how to implement the optimal n–part tariff for each firm in each quarter of the sample. After making the pertinent functional form substitutions, the equilibrium sequence of the optimal marginal tariffs $p_0 < p_1 < \ldots < p_{n-1}$ and switch types $\theta_0 < \theta_1 < \ldots < \theta_{n-1}$ are found by solving the following system of nonlinear difference equations:

$$\begin{aligned} 0 = {} & \left[\lambda \overline{\theta} - (1+\lambda)(p_k - c)\right] \left[(\overline{\theta} - \theta_{k+1})^{1/\lambda} - (\overline{\theta} - \theta_k)^{1/\lambda} \right] + \lambda \left[\theta_{k+1} - \theta_k\right] (\overline{\theta} - \theta^\circ)^{1/\lambda} \\ & - \lambda \left[\theta_{k+1} (\overline{\theta} - \theta_{k+1})^{1/\lambda} - \theta_k (\overline{\theta} - \theta_k)^{1/\lambda} \right], \qquad k = 1, \ldots, n-2 \end{aligned} \tag{16a}$$

$$\begin{aligned} 0 = {} & - \left[\lambda \overline{\theta} - (1+\lambda)(p_k - c)\right] (\overline{\theta} - \theta_k)^{1/\lambda} + \lambda \left[\overline{\theta} - \theta_k\right] (\overline{\theta} - \theta^\circ)^{1/\lambda} \\ & + \lambda \theta_k (\overline{\theta} - \theta_k)^{1/\lambda}, \qquad k = n-1 \end{aligned} \tag{16b}$$

$$0 = 2\left[\lambda(\overline{\theta} - \theta_k) + c\right] - (p_{k-1} + p_k), \qquad k = 1, \ldots, n-1 \tag{16c}$$

$$\theta_n = \overline{\theta}, \tag{16d}$$

$$p_0 = \theta^\circ, \tag{16e}$$

$$A_0 = \alpha. \tag{16f}$$

For each firm–quarter observation I numerically solve for up to seven of these systems of equations. Solving for one additional tariff option than what it is actually offered allows me to estimate the foregone rents of not offering an additional tariff, and thus evaluate firms' unobserved *product development costs*.[17] Once these sequences of switch types, marginal tariffs, and fixed monthly fees are obtained, I evaluate the expected welfare components by simulating from the distribution of types indexed by the estimated parameter λ for each firm–quarter observation. The money value per subscriber of these magnitudes are reported in Table 4 classified by the number of tariff options offered by the temporary monopolists.[18,19]

$\Longrightarrow$ INSERT Table 4: Welfare Estimates by Number of Plans $\Longleftarrow$

Table 4 presents the money value estimates of the consumer surplus, profits, welfare and foregone earnings of implementing the nonlinear tariff through only a few tariff options. There are several important results that are first illustrated in this table using actual tariff data from a particular industry application. First, as indicated by Faulhaber and Panzar (1977), welfare and its components increase with the number of tariff options offered. The rate of increase in profits, consumer surplus, and welfare decreases rapidly with the number of tariff options offered, as claimed by Wilson (1993, §8.3). Therefore, only few tariffs are needed to capture most of the gains from nonlinear price discrimination. On average, a single two–part tariff captures 89.60% of the potential consumer surplus, 96% of profits and 91.73% of the total welfare that could be attained under fully nonlinear price discrimination. With three tariff options all these percentages are in the surroundings of 99% of their respective potential levels.

Table 4 presents for the first time an estimate –based on data from a particular market– of the "money left on the table," *i.e.*, the foregone earnings of sellers due to the simplified, imperfect screening mechanisms that they use. These *product development costs* need to be high for those firms that only offer a two–part tariff because on average, these firms give up almost \$1.50 for not introducing a second tariff option. Remember that over a quarter of the sample observations belong to this category. However, once firms offer more tariff options, the foregone earnings –and consequently their unobserved *product development cost*– drop on average to \$0.34, \$0.13, \$0.06, \$0.04, and \$0.02 for two, three, four, five, and six tariff options, respectively.

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[17] To find two optimal two–part tariff options, $n-1=2$, it is necessary to solve four nonlinear difference equations with four unknowns: $\{\theta_1, \theta_2, p_1, p_2\}$. When $n-1=7$ the number of equations grows to fourteen.

[18] To identify the money magnitudes of Table 4, simulations are required to generate expected monthly payments close to \$100, which is documented as representative for this period. See the 2002 Semiannual Wireless Survey of the Cellular Telecommunications & Internet Association.

[19] As the number of tariff increases, the share of potential consumers excluded from the market shrinks. It should be noted that solving for switching types $\theta_0 < \theta_1 < \ldots < \theta_{n-1}$ already accounts for the welfare effects induced by the participation of new subscribers as the number of tariff options increases.

The magnitudes of these foregone profits are low enough to support the idea that not very expensive *product development costs* may indeed turn optimal for firms to offer only few tariff options. Table 5 presents the top–ten largest estimates of these *product development costs* at the last period of monopoly regime across markets. These estimates depend on the features od the distribution of types as summarized in Table 4, the actual number of tariff options offered, and the total number of subscribers in each market (antennas). The estimated magnitudes are quite moderate. It is not unreasonable to conclude that the research costs necessary to design an additional optimal tariff option will exceed these magnitudes. Therefore, offering few tariff option will be an optimal strategy to extract consumer surplus while minimizing *product development costs*.

$\Longrightarrow$ INSERT Table 5: Largest Foregone Profits $\Longleftarrow$

I include the sample distribution of all the estimated variables in the first and second stage of the empirical analysis of this paper at the bottom of Table 1. These magnitudes compute the welfare and foregone earnings corresponding to the actual number of effective tariffs offered by cellular carriers in each market–quarter combination. Observe that these simplistic pricing strategies achieve almost 94% of potential welfare and over 97% of potential profits of the much more involved to design, and much more difficult to implement, fully nonlinear tariff. The sample average of the foregone incremental profits amounts only to \$0.33 per customer.

$\Longrightarrow$ INSERT Table 6: Welfare and Foregone Profits $\Longleftarrow$

To complete the characterization of the approximate empirical optimality of multipart tariffs, Table 6 conducts a simple regression analysis of the share of potential welfare captured with the actual multipart tariff used, as well as the magnitude of foregone profits, on the observable characteristics of each market. The first column of Table 6 presents the results of a linear regression model for the log–odds ratio of WLFIND, that is:[20]

$$\ln\left[\frac{\text{WLFIND}_{it}}{1-\text{WLFIND}_{it}}\right] = \boldsymbol{x}_{it}\boldsymbol{\zeta} + \varepsilon_{it}. \tag{17}$$

The second column of Table 6 reports the marginal effects evaluated at the sample means of regressors, *i.e.*, the percent increase of the ratio of actual to maximum welfare due to a unit increase of each regressor. The third column of Table 5 presents a standard linear regression of the estimated *product development costs* on the same set of regressors. In both cases, results show important firm effects. The ratio of actual to potential welfare increases with commuting time, median income per capita and the number of subscribers while it gets reduced with the number of years of education, the number of business considered to be highly potential customers of the cellular industry and the marginal operating costs.

[20] This transformation ensures that the error ε_{it} is properly defined over the real line. The log–odds transformation is justified in this case because the values of WLFIND belong to the open interval $(0, 1)$.

Foregone profits decreases over time. This might perhaps be interpreted as evidence of firm learning and fine tuning of the screening mechanism as they update their knowledge of demand behavior in each market. However, firms appear to learn of their own experience or the experience of others and design better mechanisms in newer markets because the foregone profits remain significantly higher in those markets that started operating earlier. Every additional minute of commuting, an extra percent growth of the population, or an additional thousand dollars of median average income increases the average foregone rents by about one cent. However, the most important effect is by far that of education, which reduces the average foregone profits by $0.28 for each additional year of the median number of years of education.

5 Concluding Remarks

The evidence reported in this paper shows that profits from further discrimination are decreasing very rapidly with the number of options. Indeed, offering three tariff options reported them around 99% of the potential profits of fully nonlinear pricing. I estimate that the average foregone profits in the sample –*i.e.*, the lower bound of the *billing and marketing costs*– amount to 33 cents per customer (expressed in dollars of 1986). This is a small magnitude compared to the usual advertising budgets of these companies. When the effects per customer are aggregated up to the subscriber base –see Table 5– foregone incremental profits still remain small, thus justifying simple tariffs with few options.

The paper has also documented important firm effects in the magnitude of foregone profits and the ratio of actual–to–potential welfare attainable with simple *vs.* fully nonlinear tariffs. Thus, pricing practices are critically conditioned by the identity of the owner of the *wireline* license. Foregone incremental profits are more important in earlier markets but tend to decrease over time.

The paper presents with compelling evidence that simple tariffs will provide most potential gains to firms and consumers. While Wilson (1993, §8.3) proved that foregone rents decreased rapidly with the number of tariff options offered, this paper has shown that the economic magnitude of these foregone rents after two or three tariff options are offered falls well below the necessary *product development costs* associated to the design and commercialization of additional optimal tariff options. Therefore, current pricing practices of offering dozens of tariff options do not appear to be justified.

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Table 1. Descriptive Statistics and Definitions

Variable	Description	Mean	Std.Dev.	Min.	Max.
TIME	Quarterly time trend	8.6095	3.7429	1.00	15.00
MKT–AGE	Age of the market in months	15.3284	9.9486	1.00	43.00
COMMUTE	Average commuting time in minutes	25.9328	2.2216	21.90	32.10
COVERAGE	1200×TCELLS/POPULATION (×100)	0.0178	0.0230	0.00	0.24
POPULATION	Market population in thousands	1.4718	1.5366	0.05	8.51
POP–AGE	Median age of the population in years	33.0281	2.9877	25.60	41.50
EDUCATION	Median number of years of education	12.5577	0.2587	11.70	13.20
BUSINESS	Thousands of high potential business establishments	40.7213	49.2291	8.11	289.34
GROWTH	Average percent growth of population in the 1980's	1.3843	0.9820	-0.60	3.60
INCOME	Median income in 1986 thousand dollars	27.9016	3.8433	20.32	38.94
POVERTY	Percentage of households with income below poverty level	10.9759	2.8635	7.10	20.40
ESTCOST	Estimated marginal cost (dollar per minute)	0.6290	0.1425	0.21	0.93
NEAREND	Dummy: Observation belongs to the last six months prior to competition	0.2289	0.4206	0.00	1.00
TCELLS	Number of operative cells (antenna sites)	16.8682	16.4765	2.00	81.00
REGULATION	Dummy: Cellular carrier needs regulatory review and approval to change tariffs	0.4701	0.4997	0.00	1.00
AMERITECH	Dummy: Ameritech Mobile	0.0373	0.1898	0.00	1.00
BELLATL	Dummy: Bell Atlantic Mobile	0.0622	0.2418	0.00	1.00
BELLSTH	Dummy: BellSouth Mobility	0.2239	0.4174	0.00	1.00
CENTEL	Dummy: Century Cellular	0.0199	0.1398	0.00	1.00
CONTEL	Dummy: CONTEL Cellular	0.0771	0.2671	0.00	1.00
GTE	Dummy: GTE Mobilnet	0.0771	0.2671	0.00	1.00
NYNEX	Dummy: Nynex Mobile	0.0274	0.1633	0.00	1.00
PACTEL	Dummy: PacTel Mobile Access	0.1095	0.3126	0.00	1.00
SWBELL	Dummy: SouthWest Bell	0.0572	0.2325	0.00	1.00
USWEST	Dummy: US West Cellular	0.1294	0.3360	0.00	1.00
BELL	Dummy: The holder of the cellular license belonged to the former Bell System	0.0000	0.0000	0.00	0.00
PLANS	Number of non–dominated tariff options offered by firms	1.4254	0.5914	1.00	3.00
ESTCOST	Estimated marginal cost (dollar per minute)	0.6290	0.1425	0.21	0.93
CSP	Estimated consumer surplus for the number of effective options offered (×1000)	103.69	71.99	10.60	219.74
PRF	Estimated profits for the number of effective options offered (×1000)	52.97	36.73	5.52	111.09
WLF	Estimated welfare for the number of effective options offered (×1000)	156.66	108.72	16.27	330.83
MAXCSP	Estimated maximum consumer surplus under optimal fully nonlinear tariff (×1000)	107.20	74.28	11.10	223.50
MAXPRF	Estimated maximum profits under optimal fully nonlinear tariff (×1000)	53.60	37.14	5.50	111.75
MAXWLF	Estimated maximum welfare under optimal fully nonlinear tariff (×1000)	160.79	111.42	16.64	335.25
CSPIND	Ratio CSP/MAXCSP (×100)	92.2939	3.5134	89.60	98.32
PRFIND	Ratio PRF/MAXPRF (×100)	97.0661	1.3894	96.00	99.41
WLFIND	Ratio WLF/MAXWLF (×100)	93.8846	2.8054	91.73	98.68
FOREGONE	Estimated dolar value of profit increase of introducing an additional effective option	0.3272	0.2286	0.01	0.63

Sources: Cellular Price and Marketing Letter, Information Enterprises, various issues, 1984–1988; Cellular Business, various issues, 1984–1988; 1989 Statistical Abstracts of the United States, U.S. Department of Commerce, Bureau of the Census, using the FCC Cellular Boundary Notices, 1982–1987, available in *The Cellular Market Data Book*, EMCI, Inc. Welfare estimates are averages per subscriber. The full sample includes 402 firm–quarter observations.

Table 2. Number of Tariff Plans

No. Plans	Observations	Frequency
1	134	0.3333
2	87	0.2164
3	73	0.1816
4	72	0.1791
5	24	0.0597
6	12	0.0299
Mean	2.5050	
Variance	1.9962	

Sample distribution of the number of plans offered to consumers. The sample includes 402 observations.

Table 3. Distribution of Tariff Parameters

Estimates	UNIFORM		CHEBYCHEV	
α	0.0929	(0.0412)	0.0896	(0.0416)
β	0.7535	(0.1791)	0.7623	(0.1832)
γ	–0.1228	(0.1830)	–0.1332	(0.1895)
c	0.6307	(0.1474)	0.6290	(0.1425)
λ	0.0251	(0.0379)	0.0273	(0.0392)
θ°	0.7535	(0.1791)	0.7623	(0.1832)
$\overline{\theta}$	5.9286	(0.1474)	5.9269	(0.1425)

Average and standard deviation of the distribution of OLS estimates of fitting a quadratic regression of tariff payment either on a uniform grid or over Chebychev nodes of air-time use defined between 0 and 500 minutes. The sample includes 402 observations.

Table 5. Largest Foregone Profits

City	1986 Dollars
Phoenix, AZ	12,953.77
Houston, TX	11,972.23
Seattle, WA	11,896.54
Denver, CO	10,667.81
Tampa, FL	5,286.91
Salt Lake City, UT	4,584.47
Chicago, IL	3,989.00
Tucson, AZ	3,056.31
Kansas City, MO	2,271.18
Atlanta, GA	2,070.48

Estimated foregone incremental profits in the last quarter of monopoly regime.

Table 4. Welfare Estimates by Number of Plans

CONSUMER SURPLUS	
Variables	Mean

Table 6. Welfare and Foregone Profits

	WLFIND				FOREGONE	
Variables	Estimates		Marginal Effects		Estimates	
Constant	15.0640	(6.45)	0.7548	(6.36)	2.9919	(9.46)
TIME	0.0042	(0.20)	0.0002	(0.20)	–0.0069	(2.51)
MKT–AGE	0.0004	(0.06)	0.0000	(0.06)	0.0023	(2.40)
COMMUTE	0.0512	(2.47)	0.0026	(2.45)	0.0087	(2.72)
COVERAGE	–1.6841	(1.54)	–0.0844	(1.54)	–0.3084	(1.36)
POPULATION	0.0445	(0.74)	0.0022	(0.74)	0.0139	(1.89)
POP–AGE	–0.0002	(0.02)	–0.0000	(0.02)	0.0002	(0.20)
EDUCATION	–1.2337	(5.54)	–0.0618	(5.44)	–0.2813	(9.25)
BUSINESS	–0.0062	(3.99)	–0.0003	(3.90)	–0.0008	(5.38)
GROWTH	0.0246	(0.68)	0.0012	(0.68)	0.0137	(3.03)
INCOME	0.0486	(4.22)	0.0024	(4.19)	0.0109	(6.74)
POVERTY	0.0216	(1.55)	0.0011	(1.55)	0.0005	(0.29)
ESTCOST	–0.1163	(2.06)	–0.0058	(2.07)	0.0139	(1.51)
NEAREND	0.0029	(0.51)	0.0001	(0.51)	–0.0009	(1.52)
TCELLS	0.4323	(4.82)	0.0217	(4.76)	0.0760	(6.00)
REGULATION	–0.0348	(0.67)	–0.0017	(0.67)	–0.0042	(0.58)
AMERITECH	0.8908	(2.56)	0.0446	(2.61)	–0.0830	(2.48)
BELLATL	–0.4196	(3.78)	–0.0210	(3.74)	–0.1020	(6.02)
BELLSTH	–0.1664	(3.02)	–0.0083	(2.98)	–0.0324	(4.22)
CENTEL	0.9020	(4.53)	0.0452	(4.61)	0.2014	(3.43)
CONTEL	0.0636	(0.64)	0.0032	(0.64)	0.0123	(0.82)
GTE	0.8257	(8.11)	0.0414	(7.97)	0.1548	(11.42)
NYNEX	1.5174	(15.94)	0.0760	(15.78)	0.1897	(10.64)
PACTEL	0.9888	(6.15)	0.0495	(6.07)	0.1476	(7.29)
SWBELL	0.8062	(6.46)	0.0404	(6.51)	0.0720	(4.51)
USWEST	1.4351	(11.22)	0.0719	(10.55)	0.6384	(42.94)
Adj.–R^2	0.7745				0.9545	

OLS estimates using the 402 observations of the full sample. Numbers between parentheses report heteroskedastic–consistent, absolute t–statistics based on McKinnon and White (1985) approximate "jackknife" robust estimate of the covariance matrix.

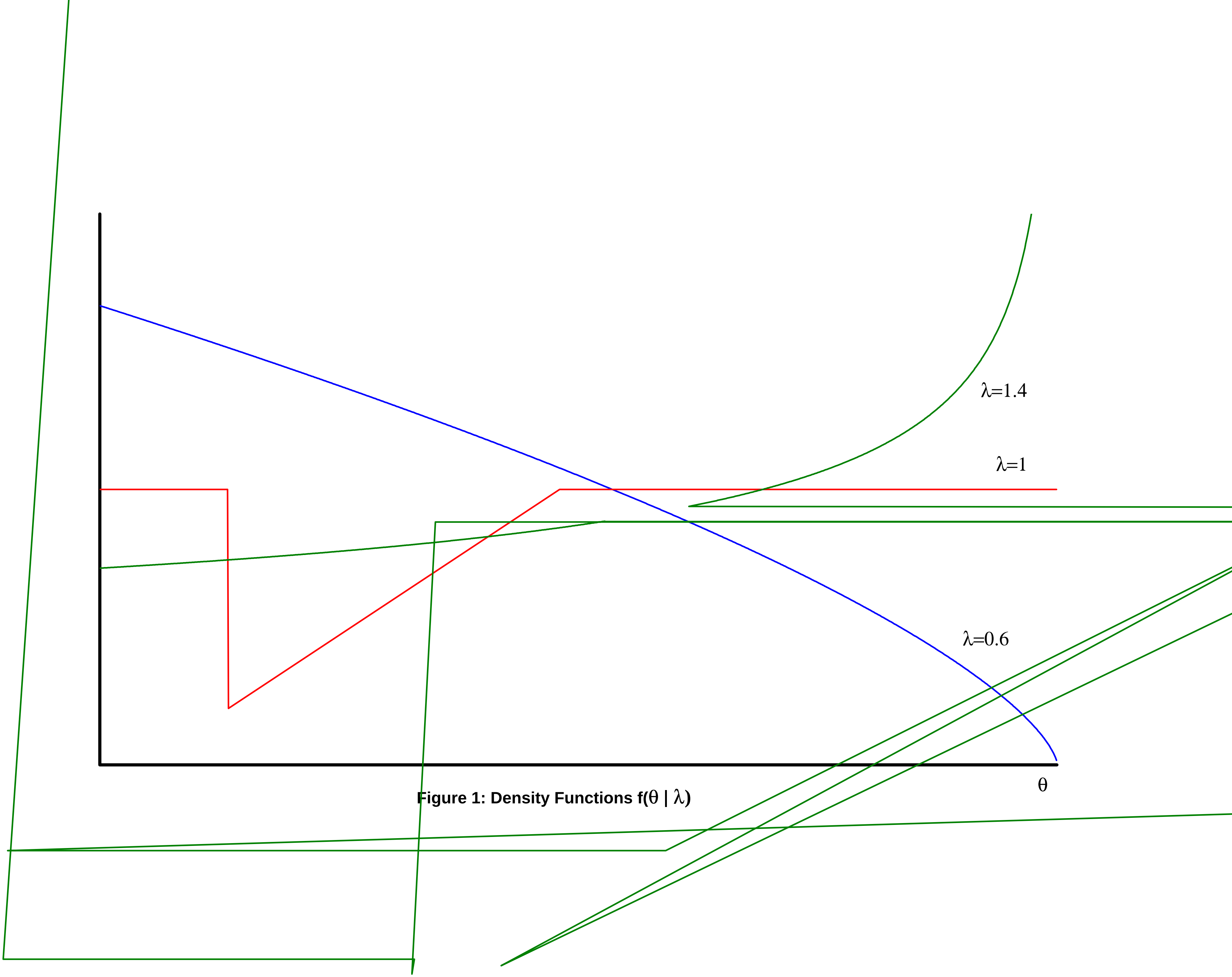

Figure 1: Density Functions f(θ | λ)

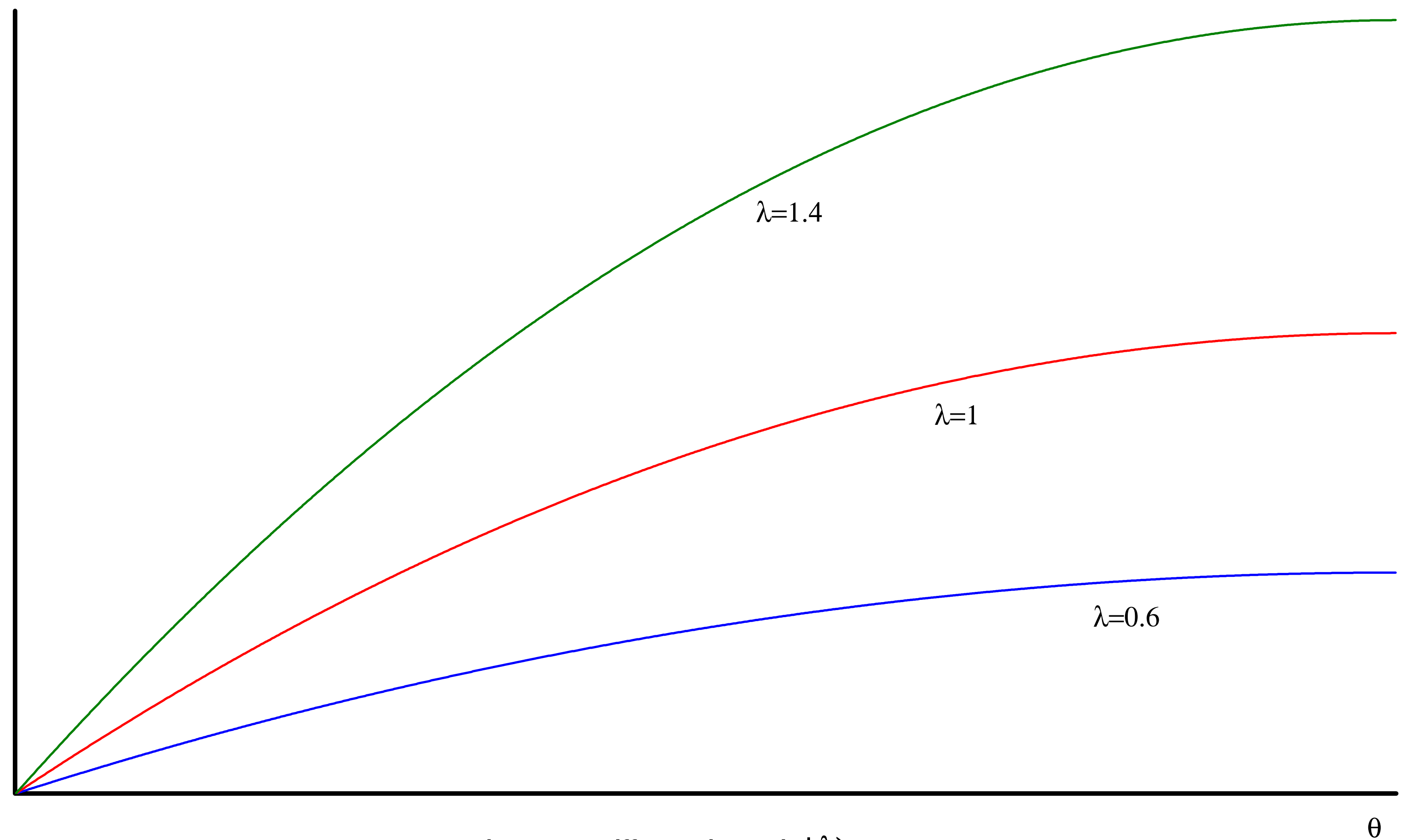

Figure 2: Tariff Functions T(x | λ)