Competition and the Use of Foggy Pricing*

Eugenio J. Miravete†

December 14, 2011

Abstract

Firms engage in *foggy pricing* when the menu of tariff options aims at profiting from consumer mistakes. The analysis of this paper concludes that the transition from monopoly to competition in the early U.S. cellular telephone industry does not generally foster the use of such deceptive strategies. I offer three alternative measures to account for the *fogginess* of the menu of options offered by cellular carriers. All results are robust to the existence of uncertainty regarding future consumption at the time of choosing a particular tariff option, as well as to consumers' heterogeneity with respect to cellular telephone usage.

Keywords: Nonlinear Pricing; Foggy Strategies; Deception; Tariff Complexity.

JEL Codes: D43, L96, M21

---

* The NET Institute (http://www.NETinst.org) offered generous financial support through its 2004 Summer Grant Program. I wish to thank Penny Goldberg, and Kenneth Hendricks, for their many constructive comments, as well as audiences at ESMT, Haas School of Business, ICE-Ludwig Maximilians Universität München, IESE, ITAM, Mannheim, Notre Dame, Wharton School, the 2006 CEPR Conference on Applied Industrial Organization (Madeira), and the 2007 Meeting of the New Zealand Association of Economists (Christchurch). I particularly thank Barry Nalebuff for his critical disagreement on the empirical approach I took in a much earlier version of this paper which forced me to address the phasing-out of old tariff options. Evidently, I am solely responsible for all errors that might still remain. A previous version circulated as CEPR DP No. 6295.

†The University of Texas at Austin, Department of Economics, BRB 1.116, 1 University Station C3100, Austin, Texas 78712-0301; and CEPR, London, UK. Phone: 512-232-1718. E–mail: *miravete@eco.utexas.edu*; http://www.eugeniomiravete.com

"Think about pricing. What has every telco in the world done in the past? It's used confusion as its chief marketing tool. And that's fine."

Theresa Gattung, Former CEO of Telecom New Zealand, 2006.

1 Introduction

The rise of behavioral economics has placed consumer choice at the center of the current regulatory debate. It is not infrequent to hear the complaint that individuals face "too many" choices. However, the number of options might be less relevant than their features. Brandenburger and Nalebuff (1996, §7) indicate that firms may use strategies that are intentionally *foggy* in an attempt to extract additional surplus from gullible consumers by making more difficult for consumers to compare the cost of the service across different providers.[1] Ellison (2005) and Gabaix and Laibson (2006) allude to the use of shrouded attributes as a way for firms to profit from inattentive consumers, and most importantly, they show that the use of shrouded attributes may arise in equilibrium in competitive markets. This is a troublesome result because, unless the market corrects the use of deceptive tactics automatically, policy makers may feel compelled to intervene in order to avoid their use for as long as the general perception prevails that consumers make systematic mistakes when choosing among contract options.[2] Indeed, current regulation proposals distrusts the market ability to correct this behavior and focus on how alternatives are presented for individuals to choose from, paying particular attention to redefining the default option. Surprisingly, there is little evidence of whether market forces exacerbate or solve the issue of abundance and complexity of choices.

[1] On this same point see Spiegler (2011, §2), who argue that the introduction of dominated options may occur if consumers have dynamically inconsistent preferences. See also the work of Ellison and Ellison (2009), who document how search engines turn demand very price-sensitive and how retailers engage in practices to frustrate consumer search to avoid the consequence of intense competition, a tactic known as obfuscation.

[2] See the *Leader* and *Britain* sections of *The Economist*, April 10th, 2004. The suspicion that competitive markets are ineffective in dealing with deception prompted the *UK Office of Fair Trading* to investigate the benefits of limiting the number of tariff options that firms can offer. For instance, see the UK Office of Fair Trading reports No. 168, No. 194, No. 255, or the 2003 British Academy Keynes Lecture on "Economics for Consumer Policy" by the Chairman, John Vickers. There have been similar investigations by the regulatory authorities of India, Perú, and other countries.

In the present work, rather than dealing with the extensively researched area of consumer behavior, I focus exclusively on the supply side of this problem, which has attracted less attention up to this point, in order to evaluate whether competition fosters or prevents the use of foggy strategies in a particular market environment. Thus, this paper makes use of data from the early U.S. cellular industry to address two questions. First, how can we characterize whether a firm's pricing strategy is *foggy*? Second, does competition affect firms' use of *foggy* strategies?

The data set used in this paper include all menus of tariff options offered by the telephone carriers of the largest one hundred cities in the early U.S. cellular industry between 1984 and 1992. While cellular telephone tariffs of the 1980s were relatively simple by today's standards, they allow me to explore alternative operationally tractable characterizations of tariff fogginess. In particular, *a particular tariff option is said to be foggy when another tariff option, or combination of other tariff options, offered by the same firm is always less expensive, regardless of the usage profile of any potential customer.* In the framework of the present application, this definition is accurate and operationally feasible given the simplicity of cellular telephone contracts in the early U.S. cellular telephone industry.

Evidence does not support the idea that the transition from monopoly to duopoly makes pricing strategies completely transparent, but, at the same time, I can rule out that competition makes tariff fogginess worse. If anything, results indicate that competition does not appear to foster the widespread use of deceptive strategies. This is an important result, although it needs to be qualified as pricing behavior differs across firms. After the entry of the second cellular carrier, incumbents do alter their pricing in a manner that slightly increases fogginess relative to the monopoly phase of the market, although this effect is temporary. Entrants, on the contrary, use foggy pricing far less frequently. These results are robust to the existence of consumers' uncertainty regarding future consumption at the time of choosing a particular tariff option as well as to consumers' heterogeneity with respect to cellular telephone usage. The use of dynamic treatment effects reveals that competition mostly has an immediate incidence on pricing. There are only minor differences in pricing behavior in the eighteen months following the entry of the second cellular carrier in each market. Furthermore, there is some weak evidence that a year after entry, the menu of nonlinear options offered by the incumbent becomes *less powerful*, as predicted by theoretical models of nonlinear pricing competition.[3]

The definition of a foggy tariff as a dominated option means that measures of fogginess reflect features of a firms' entire menu of tariff options rather than simply features of a single tariff option. Thus, I suggest three measures of the fogginess of a firm's menu of tariffs. First, I account for the number of dominated options that a firm offers. Second, I compute the ratio of dominated to non-dominated (or effective) tariff options. For both measures, I exclude those dominated options that are the result of phasing out old, previously non-dominated options that were offered to existing customers in the past but that are no longer among the tariff options offered to new customers. The first measure ranks a pricing strategy as more or less foggy depending on the absolute number of dominated options offered while the second measure looks at this number relative to how many non-dominated plans are also offered. Both measures are robust to different distributions of cellular usage. The final measure, on the contrary, is not robust to the distribution of consumer heterogeneity. The third measure addresses the "complexity" of non-dominated options, defined by the relative range of potential consumption profiles for which a particular option is the least expensive. This third measure is most reasonable for environments where consumers are uncertain about their future cellular use at the time of choosing a particular tariff plan.

The early U.S. cellular telephone industry is an almost perfect case study to analyze the effect of entry of a second competing cellular carrier on tariff fogginess. Due to an unintended failure in the license awarding process, many of these early markets operated under a monopoly

[3] Armstrong and Vickers (2001) and Rochet and Stole (2002) argue that under certain circumstances, tariffs offered by competing duopolists may simplify up to the point where the optimal pricing strategies are simply a couple of simple two-part tariffs, implying that nonlinear tariffs should become flatter with competition.

regime for a significant period of time. Eventually entry always occurred, but only after *independent* judicial decisions made market by market. Thus, the transition to competition can be considered *exogenous* of the degree of tariff fogginess of the incumbent cellular carrier. However, data do not include individual consumption and tariff choice information and the characterization of tariff fogginess has to be carried out by means of simulating numerous consumption profiles. Simulation is also employed to evaluate the robustness of results to the existence of uncertainty regarding future cellular usage and usage heterogeneity.

The paper is organized as follows. Section 2 provides some institutional background on the early U.S. cellular industry and summarizes the pricing behavior of firms, both during the monopoly and early duopoly phases of this market. Section 3 reviews the theory of nonlinear pricing in order to discuss what can reasonably be understood as foggy pricing and what could be capturing something else. This section explicitly defines the three measures of fogginess used in the paper. Section 4 evaluates the average treatment effect of entry of the second firm in each local market on the three proposed measures of fogginess. I also estimate a dynamic treatment effect model in order to sort out short and long run effects of entry of the second carrier on foggy pricing. Section 5 addresses whether results on the effect of competition on foggy pricing are robust to the existence of consumers' uncertainty regarding future cellular telephone usage. I also test whether the dispersion of the usage patterns has any effect on the significance of results. All these additional results are reported in the Online Appendix to this paper. Section 6 concludes.

2 Pricing in the Early U.S. Cellular Industry

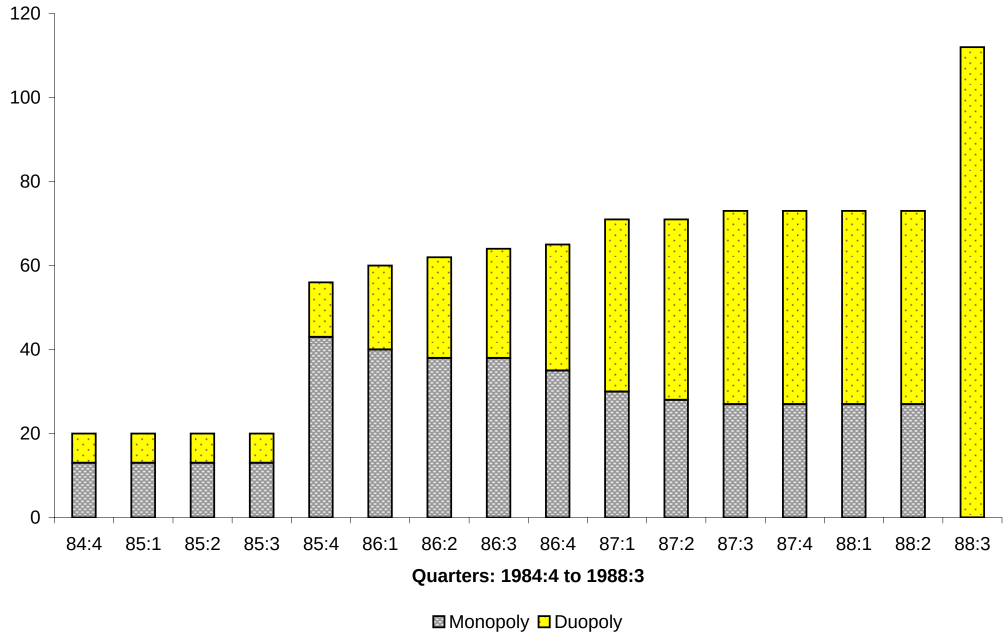
In this section I review the institutional background that makes the study of the early U.S. cellular industry valuable in determining the role of competition in firms' use of foggy pricing strategies. To summarize, only a maximum of two firms were allowed to compete in each local market, entry of the second carrier was determined by independent court decisions rather than by the pricing of the incumbent, and tariffs were sufficiently simple to allow for the accurate computation of monthly bills for multiple simulated consumer profiles. After discussing the general features of the market, I will describe the pricing behavior of firms observed in the data.

2.1 Market Description

In the early 1980s, technology was a barrier for competition, mostly because of the amount of bandwidth needed for transmission and the scarce radio spectrum available. In 1981, the *Federal Communications Commission* (*FCC*) set aside 50 MHz of spectrum in the 800 MHz band for cellular services. First, the B block channel, or *wireline license*, of each local market was awarded to a local *wireline carrier*, normally one with experience in the local telephony business. Next, the A block channel, or *nonwireline license*, was awarded by comparative hearing in each local market to a carrier other than the local wireline incumbent.

To define these local markets, the *FCC* divided the U.S. into 305 non–overlapping markets corresponding to Standard Metropolitan Statistical Areas (*SMSA*s). Licenses were awarded in ten tiers from more to less populated markets, beginning in 1983. Wireline licensees offered the service first and enjoyed a temporary monopoly position until the holder of the nonwireline license entered the market. As documented by Vogelsang and Mitchell (1997, p.207), in order to foster competition and usage of cellular service, the *FCC* required wireline carriers to offer unrestricted resale of its service until the nonwireline company was fully operational. Entrants had six months to be able to offer the service from the time they were awarded the license. Because of the *FCC* regulation in this early market, the entrant only needed to be able to establish interconnection with the incumbent's network to immediately have access to the same coverage area and potential customers of the wireline firm as it could effectively free ride on the incumbent's deployed antennae.

Figure 1: Number of Monopoly and Duopoly Markets



Despite this temporary regulation and market design, effective entry of the second carrier in the largest markets was commonly delayed. Depending on the market, there were between 6 and 579 contenders for a single nonwireline license. Those denied a license customarily appealed these administrative decisions in court. Legal disputes lingered, sometimes for years, until independent judicial decisions settled who was the rightful owner of each nonwireline license.[4] The decentralized nature of these judicial decisions is key for the present application as it leads to exogenous sample variation of the duration of the monopoly phase in each market. Between 1984 and 1988 the data includes pricing information from monopoly and duopoly markets where we can safely assume that entry of the second firm is exogenous in the sense that it is not triggered by the nature of the pricing strategies of the incumbent. Figure 1 shows the timing of the transition from monopoly to duopoly between 1984 and 1988. The time variation of this transition is sufficiently spread out, making this data particularly useful for analyzing the effect of competition on the use of foggy pricing.

[4] After this debacle the *FCC* adopted rules to award the remaining nonwireline licenses through lotteries. Those markets are not included in the sample. See Hausman (2002), Parker and Röller (1997), or Murray (2002).

2.2 Data

Data comprise tariff information for 112 markets covering over 40% of the U.S. population. These markets, averaging 1.6 million residents, are large compared to the national average of 542,000 inhabitants across all *SMSA*s in 1987. Data combine two separate databases. Tariff information from 1984 to 1988 was collected by *Economic and Management Consultants International, Inc*, and includes periods with both monopoly and duopoly market configurations. It should be noted that these markets operated independently of each other. Because of the judicial decisions described above, the identity of the entrant and the timing of entry of the second firm can be considered largely exogenous. This information is complemented with data collected by Marciano (2000) for the year 1992, when all markets had already been served by two competing firms for quite some time.[5] Including the 1992 data adds observations from more mature markets and allows me to identify whether pricing strategies are qualitatively different when one firms grows at the expense of the competing carrier rather than by expanding the customer base.

Tariffs in the early U.S. cellular industry were quite simple. A tariff option was normally a three-part tariff consisting of a fixed monthly fee, an allowance of “free” minutes per month, and a fixed rate per minute for any cellular use exceeding the allowance. Pricing distinguished between peak (comprising on average about 13 hours a day at that time) and off-peak marginal rates. Thus, the available combination of monthly fee, marginal rates and usage allowance defines the tariff option quite accurately. The richness of the tariff information contained in the data contrasts with the lack of information on individual tariff choice and monthly telephone usage. Thus, I simulate the monthly bill for each possible tariff choice for hundreds of thousands of different consumer profiles, ignoring additional roaming and other value added service changes.[6]

[5] I am grateful to Arie Beresteanu for sharing this 1992 data with me. In this paper I use the complete data set collected by Marciano (2000) and not only the subsample of markets that she uses in her dissertation.

[6] Roaming did not even exist at the beginning of the 1984-88 period and it is not included in any of the tariff options of the database. Roaming charges are carrier specific rather than tariff option specific and thus do not influence whether a particular tariff option is more or less likely to be characterized as foggy. Other value added

Consumer profiles are defined by the total duration of monthly calls during peak and off-peak times. A particular tariff option is dominated, or foggy, if for all five hundred thousand usage profiles considered, it is *always* more expensive than any of the other tariff options offered by that carrier. Notice that because I observe the whole history of tariffs offered by each firm in each market, I can identify tariff options that are dominated as a consequence of being phased-out. In practice, I do not know whether anybody subscribes to such a tariff, or if among its subscribers, we only find those who remain locked-in to some long term contract. Thus, I will ignore these phased out foggy options and consider only those that are offered to potential customers for the first time.

Since I do not observe the plans individuals subscribe to, I initially assume that individuals know their consumption profile and pick the plan that is least expensive for that consumption profile. Telephone usage is assumed to follow a beta distribution, $\beta(4/21, 1)$, with representative mean monthly usage of 160 minutes. Because the time of day when the allowance of free minutes could be consumed is unspecified for most tariff options observed in the data, I decided to split the free minutes between peak and off-peak consumption proportionally to the total usage of peak and off-peak minutes for each simulated usage profile. This is a potential source of measurement error in the computation of fogginess that will enter the error term of the estimated econometric models, as discussed below. Later, in Section 5, I address the more realistic case of consumers that are uncertain about their future usage at the time of choosing tariffs. Accordingly, I repeat the analysis for different distributions of usage and degrees of uncertainty regarding future consumption.

Does competition foster the use of foggy pricing? Table 1 shows that in monopolistic markets, one third of the firms only offered a single tariff option, and almost 40% offered between 2 and 3 options only. The transition from monopoly to duopoly clearly increased the alternatives available for consumers to choose from. About 62% of incumbents and 54% of entrants offered between 3 and 4 tariff options while fewer than 3% of incumbents and 9% of entrants offered only

services, such as detailed billing, call waiting, no-answer transfer, call forwarding, three way calling, busy transfer, call restriction, and voice mail, were priced independently and rarely bundled together with particular tariff options.

Table 1: Frequency Distributions of the Number of Tariff Options (1984-1988)

	Monopoly		*Duopoly*			
	Incumbent		*Incumbent*		*Entrant*	
TOTAL	Frequency	Rel.Freq.	Frequency	Rel.Freq.	Frequency	Rel.Freq.
1	134	0.3252	14	0.0269	48	0.0949
2	87	0.2112	71	0.1363	75	0.1482
3	73	0.1772	198	0.3800	118	0.2332
4	76	0.1845	128	0.2457	157	0.3103
5	28	0.0680	63	0.1209	54	0.1067
6	14	0.0340	47	0.0902	54	0.1067
Mean/(Var.)	2.5607	(2.0863)	3.5681	(1.4651)	3.5059	(1.9732)
FOGGY	Frequency	Rel.Freq.	Frequency	Rel.Freq.	Frequency	Rel.Freq.
0	195	0.4733	96	0.1843	127	0.2510
1	92	0.2233	151	0.2898	144	0.2846
2	83	0.2015	180	0.3455	136	0.2688
3	28	0.0680	75	0.1440	62	0.1215
4	14	0.0340	17	0.0326	30	0.0593
5			2	0.0038	7	0.0138
Mean/(Var.)	1.4879	(0.4986)	1.5624	(1.1466)	1.4960	(1.5218)

Absolute and relative frequency distribution of the number of actual and foggy (dominated) tariff options offered by each active firm in each market-quarter combination. A particular tariff option as foggy if it is more expensive than any other tariff option or a combination of other tariff options for any possible usage profile.

one option. However, not all these new offerings were genuine. The second half of Table 1 reports the frequency distribution of tariff plans that are dominated by others offered by the same firm, *i.e.*, foggy options. Incumbents increased the number of foggy options offered once they faced a competitor. The percentage of incumbents offering one foggy option increased to 29% (up from 22%). The increase is more acute for those firms offering two foggy options, increasing to 35% (up from 20%). The fogginess of tariffs offered by entrants, on the other hand, is not statistically distinguishable from that of incumbents during the monopoly phase.

From Table 1 we might conclude that an increase in the number of options available to consumers could be an attempt to benefit from mistaken choices by consumers or to soften competition. To that end, we must address whether a larger number of options offered consists mostly

Table 2: Actual vs. Foggy Number of Tariff Options (1984-1988)

Monopoly	0	1	2	3	4	5
1	32.52					
2	8.01	13.11				
3	6.31	4.85	6.55			
4	0.49	4.37	7.77	5.83		
5	0.00	0.00	5.83	0.97		
6	0.00	0.00	0.00	0.00	3.40	0.00
Duopoly — Incumbent	0	1	2	3	4	5
1	2.69					
2	9.79	3.84				
3	5.76	20.35	11.90			
4	0.00	4.80	16.89	2.88		
5	0.19	0.00	3.84	8.06	0.00	
6	0.00	0.00	1.92	3.45	3.26	0.38
Duopoly — Entrant	0	1	2	3	4	5
1	9.49					
2	8.70	6.13				
3	3.75	7.91	11.66			
4	1.19	13.04	10.47	6.32		
5	1.98	1.38	4.55	2.77		
6	0.00	0.00	0.20	3.16	5.93	1.38

Percentage of total cases for each tariff combination. Rows denote the number of total tariff options while columns are the number of foggy (dominated) tariff options. Kendall's τ measures of the correlation among the count numbers of effective and foggy options offered by each firm are: 0.7579 for the monopoly sample, 0.7467 for the incumbent in duopoly, and 0.6282 for the entrant in duopoly. The corresponding t-statistics are (22.98), (25.48), and (21.13), respectively.

of dominated or non-dominated options. Table 2 shows that the number of foggy options varies substantially with the total number of tariff options offered. For instance, during the monopoly phase, 13.11% of all options offered were dominated in situations where a firm offered just two options. With competition, this percentage dropped to 3.84% for the incumbent and 6.13% for the entrant. On the contrary, firms offering three foggy alternatives out of five options represent only 0.97% of cases in monopoly while this situation accounts for 8.06% of the pricing for incumbent and 2.77% for the entrant in competition. Therefore, because there are movements in opposite directions, the effect of competition on the fogginess of tariffs offered is ambiguous.

Table 3: Descriptive Statistics (1984-1988)

	Monopoly		*Duopoly*			
	Incumbent		*Incumbent*		*Entrant*	
Variables	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
PLANS	2.5607	1.4444	3.5681	1.2104	3.5059	1.4047
EFFPLANS	1.5850	0.7642	1.9789	0.7082	2.0099	0.9408
FOGGY (ϕ_0)	0.9757	1.1159	1.5893	1.0526	1.4960	1.2336
SHARE-FOGGY (ϕ_1)	0.2739	0.2768	0.4078	0.2219	0.3722	0.2633
COMPLEXITY (ϕ_2)	0.3680	0.5451	0.6886	0.5704	0.5894	0.5968
WIRELINE	1.0000	0.0000	1.0000	0.0000	0.0000	0.0000
DUOPOLY	0.0000	0.0000	1.0000	0.0000	1.0000	0.0000
AP_{peak}	0.0911	0.5363	0.2603	0.3132	0.0919	1.9176
$\text{AP}_{\text{off-peak}}$	0.5845	3.2887	-11.2009	99.4176	1.0395	45.7270
AVGLEAD			2.3455	2.2544	2.3702	2.2583
AVGSHAREFOGGY			0.2595	0.2134	0.2622	0.2135
AVGCOMPLEXITY			0.4204	0.3658	0.4215	0.3628
Observations	412		521		506	

All variables are defined in the text.

The unconditional analysis of Table 1 appears to hint at a slight increase in fogginess, although mostly by the incumbent firm. The entrant relies less on deceptive pricing, and thus, the overall effect of competition is unclear. The contingency analysis of Table 2 shows that while one foggy option out of few is less likely to happen in competition, competing carriers may engage more frequently in offering some foggy options out of many. The conditional evidence is thus also inconclusive and shows that motives influencing the use of foggy pricing are different depending on the incumbency status of the carrier and the total number of tariffs offered to customers. To evaluate the effect of entry on foggy pricing, I estimate a treatment effects model in which I control for market and time fixed effects separately for incumbent and entrant firms. The goal of this *differences-in-differences* (DID) analysis is to evaluate the impact that the transition from monopoly to duopoly has on the deceptive nature of pricing, *i.e.*, the effect of the dummy variable DUOPOLY, which equals one starting in the quarter when the entrant carrier started offering cellular services.

Table 3 reports the descriptive statistics of the variables used in the econometric analysis, each of which is observed on a market-quarter basis for each active firm. Variables include the number of tariff plans offered by a firm(PLANS), how many of these plans are non-dominated (EFFPLANS) and dominated (FOGGY(ϕ_0)), the ratio of newly dominated to total non-dominated tariffs (SHARE-FOGGY(ϕ_1)), and a measure of the complexity of the menu of non-dominated options (COMPLEXITY(ϕ_2)) defined below in Section 3.3. Table 3 also includes AP_{peak} and $\text{AP}_{\text{off-peak}}$, two "Arrow-Pratt analogue" measures of the curvature of the peak and off-peak dimension of tariffs. Variable AP_{peak} is the equivalent of the Arrow-Pratt measure of risk aversion averaged over the 0-1000 minute interval of airtime usage of the quadratic polynomial that fits the lower envelope of the peak component of the tariff. Variable $\text{AP}_{\text{off-peak}}$ is defined similarly but using the off-peak component of the tariff.

3 Tariff Fogginess: Definitions and Theoretical Background

Sellers commonly face consumers with heterogeneous willingness to pay for their product or services. In the case of services, second degree price discrimination is easier to implement because arbitrage among customers with different valuation can be avoided easily as personal services are more difficult to resell. Single-dimensional screening of consumers is now a well settled area of the information economics field. The basic idea is that the seller can design an optimal contract, a nonlinear tariff that charges different markups to individuals who consume different amounts, in order to maximize expected profits while giving all consumers the appropriate incentives so that they behave according to their preferences rather than mimicking consumers of different types. Thus, Section 3.1 provides a brief discussion of how the solution to this nonlinear pricing problem is linked to the basic elements of the model (preference and asymmetric information parameters). The optimal nonlinear tariff solution provides a natural point of departure to discuss what a foggy option is and how tariff fogginess can be characterized, both of which I address in Section 3.2.

3.1 Optimal Fully Nonlinear Tariff

A firm produces x at a constant marginal cost c and offers a nonlinear tariff $T(x)$ to maximize profits $\pi(x) = T(x) - cx$. Consumers have heterogenous preferences over x denoted by the utility function $U(x, \theta) = \theta x + bx^2/2$. The single-dimensional taste parameter, θ, is private information for each consumer. The concavity of the utility function captured by parameter b is common to all consumers in the market. This parameter is effectively the inverse of the slope of individual direct demand functions. The seller only knows its distribution, $\theta \sim F(\theta) = 1 - (1-\theta)^{1/\lambda}$ on $\theta \in [0, 1]$ for $\lambda > 0$. The mean of the distribution, $\lambda/(1+\lambda)$, increases with the proportion of high valuation customers, which is directly related to λ. The rent of a consumer of type θ is:

$$\mathcal{U}(\theta) = \theta x(\theta) + \frac{b}{2}x^2(\theta) - T\left(x(\theta)\right) . \tag{1}$$

There are two sufficient conditions for the nonlinear tariff solution to be well behaved in the sense of avoiding bunching, *i.e.*, making sure that any two different consumer types are charged a different amount for their optimal purchase. The first is known as the *single-crossing property* (*SCP*), which refers to being able to unambiguously order consumer demands for any given price. The second sufficient condition requires that the distribution of the asymmetric information parameter θ is smooth enough in the sense that there is not *too much* mass of probability concentrated around any given value of θ. Formally, this translates into the distribution of types, $F(\theta)$, belonging to the increasing hazard rate ordering:[7]

Given these two assumptions and the distribution of types, the monopolist designs the optimal tariff by maximizing expected profits, subject to two restrictions, namely the *individual rationality* (*IR*) and *incentive compatibility* (*IC*) constraints. The *IR* constraint is the constraint

[7] The hazard rate of the probability distribution function $F(\theta)$ is ensured to be increasing if the probability density function $f(\theta) = F'(\theta)$ is log-concave. See Miravete (2011, Proposition 1) for a proof of this statement.

that consumers will only consume if doing so is weakly preferable to not consuming; consequently, *IR* defines the lowest active consumer type, θ_0, for which $x(\theta_0) = 0$, *i.e.*, $\underline{\mathcal{U}} \equiv \mathcal{U}(\theta_0) \geq 0$. Conversely, *IC* requires that each consumer does not attempt to mimic the optimal behavior of any other consumer type when choosing how much to purchase of the good or service, *i.e.*, that she *truthfully* reveals her own type by choosing the optimal level of consumption according to her willingness to pay: $U\left(x(\theta), \theta\right) \geq U\left(x(\theta'), \theta\right)$, $\forall\, \theta, \theta'$. The local version of this *IC* constraint can be written as follows:

$$\theta \in \underset{\theta'}{\operatorname{argmax}} \left\{ \theta x(\theta') + \frac{b}{2} x^2(\theta') - T\left(x(\theta')\right) \right\}. \tag{2}$$

The solution of this direct revelation mechanism is a nonlinear contract $\{T(\theta), x(\theta)\}$ that allocates the optimal consumption, $x(\theta)$, and optimal payment, $T(\theta) = T\left(x(\theta)\right)$, to each consumer type θ. The necessary condition to characterize this optimal contract is:

$$\theta - bx(\theta) = c + \lambda(1 - \theta), \tag{3}$$

which indicates that marginal tariff (left hand side) equals the marginal cost plus an optimal markup that is increasing in λ but decreases with θ. Indeed, this markup completely vanishes for $\theta = 1$, so that the highest consumer type is the only one efficiently priced. After making use of this condition, the optimal consumption is given by:

$$x(\theta) = \frac{(\theta - c) - (1 - \theta)}{b}. \tag{4}$$

Telephone usage data is not available. However, the data is rich in tariff information. The other component of the optimal contract is the following nonlinear tariff:

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

We could speculate whether a two-part tariff is simpler, or perhaps less foggy, than any fully nonlinear schedule. The distinction would be misleading because the seller is not aiming at profiting from any potential mistakes of consumers. Tariffs have different degrees of concavity simply because they respond to heterogeneity among potential customers. Oi (1971) observes that if all consumers are alike, a simple two-part tariff, such as "Schedule A" of Figure 4 in the Online Appendix, suffices to extract all consumer surplus and achieves the first best solution: the marginal charge should equal marginal cost and the fixed fee amounts to the size of the associated consumer surplus. This corresponds to the case above where the distribution $F(\theta)$ is degenerate, *i.e.*, when $\lambda = 0$. If consumers are heterogeneous, different unit prices need to be offered to each consumer type in order to extract as much surplus as possible while avoiding arbitrage, *i.e.*, violation of the IC condition (2). The larger is the proportion of high valuation customers, *i.e.*, for larger values of λ, the higher are the markups that firms need to charge for low usage customers. This ensures that the offered tariff is an incentive compatible contract that dissuades high valuation customers from mimicking the behavior of low valuation ones. Thus, tariffs need to be *more powerful* (more concave) the more numerous high valuation customers are (high λ)..[8]

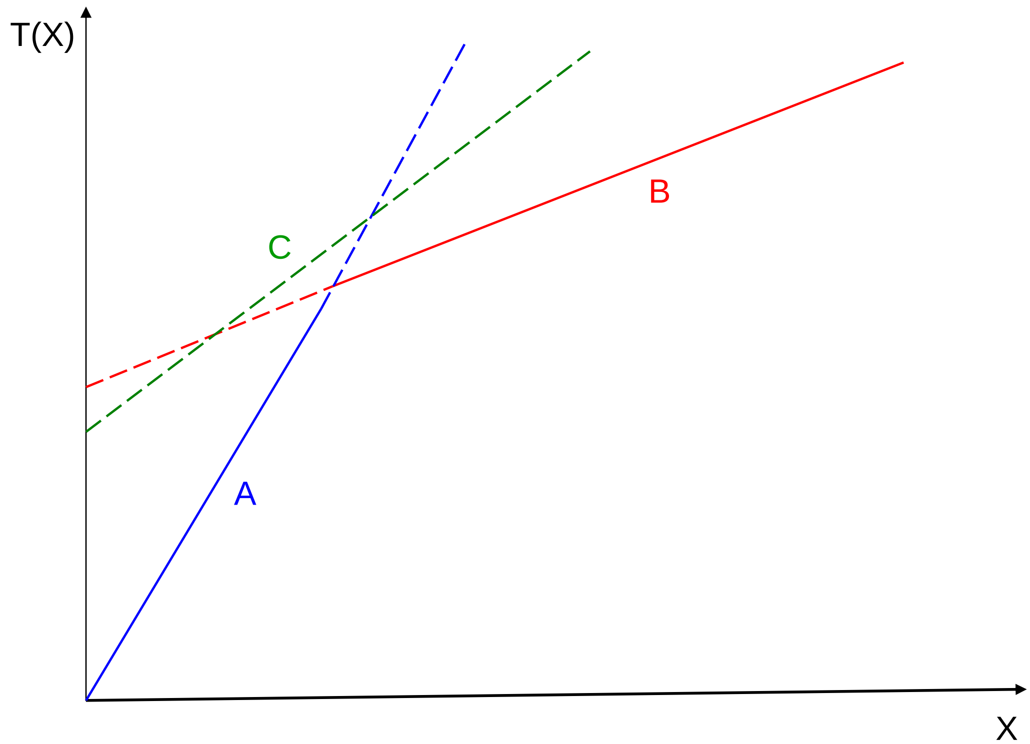
3.2 Fogginess: Operational Definitions

Any of the tariffs represented in Figure 4 can be understood as the lower envelope of a continuum (infinite number) of two-part tariffs. Thus, the number of options included in a menu of tariffs is of little value for characterizing the fogginess of a tariff, and more precise definitions are needed in order to conduct a meaningful empirical analysis.

I define a particular tariff option as foggy if it is more expensive than another tariff option or a combination of other tariff options for any possible usage profile. If consumers subscribe to a

[8] This result is formally proven by Maskin and Riley (1984) and Wilson (1993), and is behind the empirical strategy of Busse and Rysman (2005) to test the effect of competition on the shape of nonlinear pricing of advertising in yellow pages.

Figure 2: Fogginess: Dominated Tariff Option



foggy tariff option, they could always reduce their expenses afterwards by switching to a different tariff plan. This situation is depicted in Figure 2. Option C is foggy because any consumer will always pay less by subscribing to option A if she uses the telephone sparsely or to option B if she is an intensive cellular customer.[9] The tariff of Figure 2 is defined over a single-dimensional usage measure, "X", but in practice it generally involves many other dimensions such as peak and off-peak time, day of the week, or network where calls are terminated, among others. Notice also that this definition of a foggy tariff is robust to the existence of unobserved heterogeneity of consumers regarding their usage intensity: whether cellular use is uniformly distributed ($\lambda = 1$), concentrated at high consumption ($\lambda > 1$), or concentrated at low consumption ($\lambda < 1$), Tariff C is always more expensive than any of the alternatives.

[9] Strictly speaking, this characterization of a foggy tariff corresponds to the case where consumers are certain about their future usage, an assumption that I will later relax in Section 5.

In order to determine whether an option is dominated or not, I simulate the offered tariff plans of each firm in each market and time period over all possible combinations of peak and off-peak consumption adding up to a maximum of 1000 minutes of airtime usage.[10] A particular option is foggy if it is never the least expensive one for at least one of 501,501 potential usage patterns. I account for the possibility of some foggy tariffs being the result of phasing out of old effective tariffs by focusing only on those that are offered to new customers. The simplest measure of fogginess is the total number of dominated tariff options:

$$\phi_0 = \text{Number of Newly Dominated Options}\,. \tag{6}$$

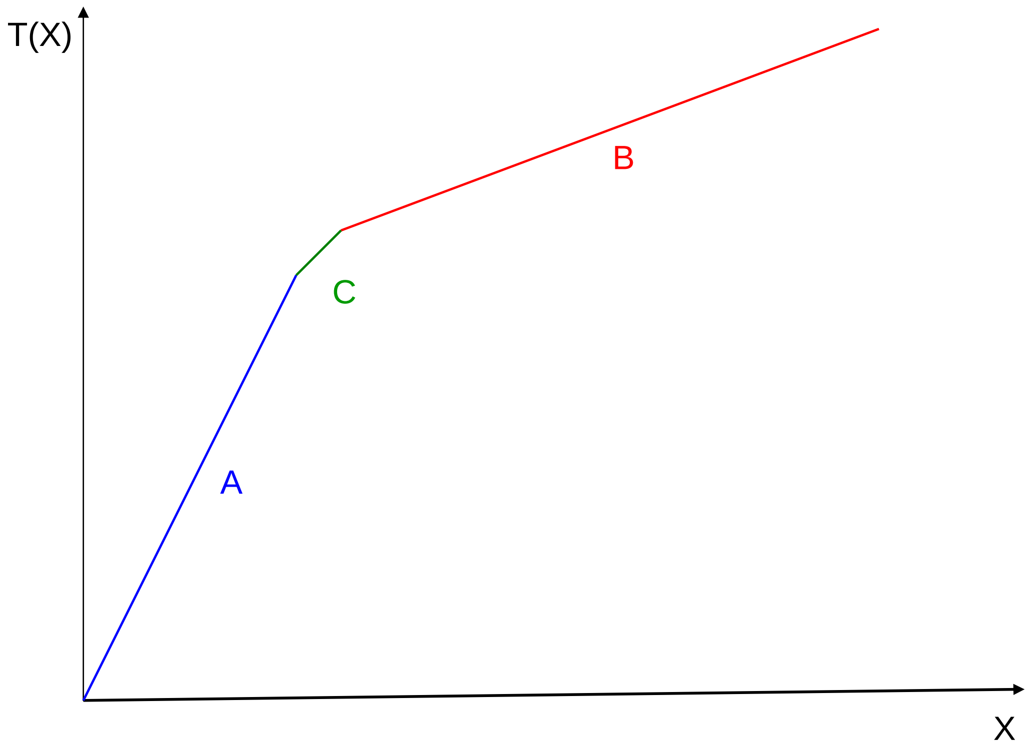
Knowing if a particular tariff is foggy, we can easily characterize the fogginess of a menu of tariff plans as being proportional to the ratio of dominated to non-dominated tariff options:

$$\phi_1 = \ln\left(\frac{\text{Number of Newly Dominated Options}}{\text{Number of Non}-\text{Dominated Options}} + 0.1\right). \tag{7}$$

Notice again that this measure is robust to the existence of consumer heterogeneity regarding usage patterns. A tariff option may be the least expensive one only when customers call between 650 and 655 peak minutes and 350 and 345 off-peak minutes. It is irrelevant, however, whether such profiles are common or rare. What matters is that this tariff option is not always dominated by a combination of the other options. Furthermore, this measure of fogginess increases with the proportion of dominated options relative to non-dominated options. Thus, according to ϕ_1, the pricing of a firm that offers one foggy and one effective tariff is more foggy than that of a firm offering two foggy and three non-dominated options. Fogginess, as measured by ϕ_0, would rank these two firms in the opposite way.

[10] Usage patterns do not necessarily need to add up to 1000 minutes. I simply exclude the possibility that the sum of peak and off-peak consumption exceeds 1000 minutes. Hausman (2002) reports that the average cellular telephone airtime usage in the U.S. reached 160 minutes per month in 1992.

Figure 3: Fogginess of Tariff Lower Envelope



3.3 Tariff Complexity

Firms do not commonly offer fully nonlinear tariffs, but instead offer a menu of a few tariffs options. Figure 3 is a more accurate representation of the environment of the present application. All options represented in Figure 3 are non-dominated and define the lower envelope of the tariff offered by a particular carrier, and in principle we can rule out any attempt at using foggy tactics, particularly if consumers are certain about their future telephone usage. Within this framework of lack of uncertainty, the fact that tariff option C is the least expensive option for a much smaller range of consumption than options A and B indicates that there is a sizeable mass of customers with usage patterns around that particular level of consumption ("sweet spot"). Thus, any firm could find it profitable to offer a tariff option to this group of consumers without any intent to induce them to sign up for unnecessarily expensive tariff options.

However, it could also be argued that fogginess measures ϕ_0 and ϕ_1 overlook other more sophisticated tactics to deceive consumers. In the presence of individual uncertainty regarding future usage, tariff option C in Figure 3 may mainly be offered to take advantage of potential usage prediction bias rather than to screen customers with respect to their consumption. The tariff of Figure 3 would appear unbalanced if the distribution of expected usage was uniform but not if the mass of probability were concentrated around the consumption range of tariff option C. Contrary to ϕ_0 or ϕ_1, any measure of complexity of the tariff lower envelope that addresses the possibility to benefit from consumers' wrong choices under uncertainty will not be robust to different distributions of consumer types. Therefore, the index of complexity of non-dominated tariff options needs to accommodate potential asymmetries regarding the share of usage patterns for which they are the least expensive option. I define the complexity index of a non-dominated set of tariff options as:

$$\phi_2 = \ln\left[\zeta + 0.1\right] = \ln\left[(n \cdot HHI - 1) + 0.1\right] , \tag{8}$$

where n is the number of non-dominated options defining the tariff lower envelope and HHI is the Herfindahl-Hirschman index of concentration of the share, s_i, of usage patterns for which each plan is the least expensive one. The HHI is given by:

$$HHI = \sum_{i=1}^{n} s_i^2 \,. \tag{9}$$

Considering only "balanced" tariff schedules in which each plan is the least expensive for the same $s_i = 1/n$ share of usage patterns, $\zeta = 0$ regardless of n, the number of tariff options offered. Because HHI increases with the asymmetry of the distribution of shares of the least expensive usage patterns of each tariff option (see Tirole (1989, §5.5)) this latter index of fogginess is larger for less balanced menus of tariffs, *i.e.*, more complex menus that offer options that are the least expensive ones for very limited consumption ranges.

Evidently, ϕ_2 depends critically on the assumed distribution of usage, whether uniform or otherwise. The distribution of telephone usage is quite asymmetric, with a large mass around low usage levels and a long and thin right tail, *e.g.*, Miravete (2005, Figures 4(a)-4(b)). Since individual consumption data are not available, I simulate usage profiles to compute tariff fogginess, weighting each usage profile in the range 0-1000 with the probability of a beta distribution, $\beta(4\kappa/21, \kappa)$ for $\kappa = 1, 2, \ldots, 5$ with support also on 0-1000. All these distributions have a mean of 160 minutes (identical to the average monthly cellular telephone usage in 1992, a variance that decreases with κ, and most of their mass of probability around low consumption levels.

4 Foggy Pricing: From Monopoly to Competition

The econometric analysis regresses each of the foggy measures of Section 3 on the dummy DUOPOLY, which takes value one when the second carrier has entered the market:

$$\phi_{ijmt} = \alpha + \beta \mathbf{x_{jmt}} + \gamma \text{DUOPOLY}_{jmt} + \mu_m + \nu_t + \varepsilon_{jmt}\,, \tag{10}$$

where $i = 0, 1, 2$ indexes the three foggy measures, $j = 0, 1$ denotes the incumbent status of the firm (with $j = 1$ identifying the incumbent WIRELINE carrier), m refers to each *SMSA*, and t is a quarter indicator running from the 4th quarter of 1984 to the 3rd quarter of 1988, plus 1992. The error term includes market, μ_m, and time, ν_t, specific effects plus a stochastic error, ε_{jmt}. Fogginess may vary across markets and time depending on the penetration of cellular service, how sophisticated consumers are in each market, or how quickly they learn. The idiosyncratic error component includes measurement error due to unspecified allocation of the allowance of free minutes to peak and off-peak cellular consumption, the existence of some other hidden items such as phone rental surcharges, or any discrepancy between the proposed measures and what individuals may consider foggy, such as risk or loss aversion.

In addition to the market structure average treatment of interest, the regression includes $\mathbf{x_{jmt}}$, a set of tariff specific features, AP_{peak} and $\text{AP}_{\text{off-peak}}$, related to the degree of concavity of the tariff lower envelopes of the tariff over peak and off-peak consumption, respectively. The logic for including these regressors is the following. If consumer taste heterogeneity is given, parameter λ, the proportion of high to low valuation customers is also given for each market and period. The solution of the nonlinear tariff of Section 3.1 critically depends on this indexing parameter of the distribution of asymmetric information. If this equilibrium interpretation is correct, AP_{peak} and $\text{AP}_{\text{off-peak}}$ are exogenous regressors and come determined by market specific characteristics related to the nature of consumer heterogeneity. But alternatively, it could be argued that AP_{peak} and $\text{AP}_{\text{off-peak}}$ are computed using the tariff plans actually offered by the firm, and that indeed the concavity of the tariff is determined exclusively by the pricing decisions of firms rather than capturing any effect of consumer heterogeneity. In this case, AP_{peak} and $\text{AP}_{\text{off-peak}}$ would be endogenous. Tests of exogeneity favor the interpretation that AP_{peak} and $\text{AP}_{\text{off-peak}}$ reflect given market conditions. Thus, in this section, I do not instrument for these regressors. In the next section, I discuss an instrumentation strategy to test for the exogeneity of these regressors and report results for these instrumental regressions.

Table 4 evaluates the average treatment effect of DUOPOLY, *i.e.*, the effect that the transition from monopoly to duopoly has on the deceptive nature of pricing strategies employed by early cellular carriers. The top of the table refers to the incumbent and the bottom to the entrant. In the first case, the data comprises pricing behavior of the incumbent only over the monopoly and duopoly phases of the market. In the second, the monopoly phase includes the pricing of the incumbent while the duopoly phase includes only the pricing behavior of the entrant. I proceed in this way, rather than by pooling the pricing behavior of the incumbent and the entrant during the duopoly phase, to avoid potential strategic effects that would make these alternative methodologies for identifying the effects of competition on pricing practices a much more involved task.

Table 4: Fogginess – Average Treatment Effects

INCUMBENT	ϕ_0 $(PMLE)$		ϕ_1 (OLS)		ϕ_2 (OLS)	
YEAR92	0.0183	(1.84)	0.0304	(0.76)	0.0634	(0.74)
DUOPOLY	0.0069	(1.42)	0.0437	(2.25)	0.1159	(3.42)
AP_{peak}	0.0091	(1.86)	0.0080	(0.20)	0.0180	(0.31)
$\text{AP}_{\text{off-peak}}$	0.0000	(1.04)	0.0000	(0.10)	−0.0004	(3.44)
$DPLRI$/ $Adj.R^2$	0.5964		0.6808		0.6806	
LM(Joint Test)	2.9383	[0.2301]	0.2988	[0.5847]	0.0063	[0.9370]
ENTRANT	ϕ_0 $(PMLE)$		ϕ_1 (OLS)		ϕ_2 (OLS)	
YEAR92	−0.0007	(0.17)	−0.0095	(0.28)	0.4117	(4.76)
DUOPOLY	−0.0006	(0.27)	−0.0440	(2.12)	0.0261	(0.72)
AP_{peak}	−0.0016	(3.51)	−0.0144	(2.56)	0.0126	(2.00)
$\text{AP}_{\text{off-peak}}$	−0.0000	(0.96)	−0.0001	(0.03)	0.0003	(0.03)
$DPLRI$/ $Adj.R^2$	0.6401		0.6958		0.6576	
LM(Joint Test)	3.8424	[0.1464]	1.4979	[0.2210]	4.5913	[0.0321]

Marginal effects evaluated at the sample mean of regressors and absolute, heteroskedastic-consistent t-statistics are reported in parentheses. $DPLRI$ is the Poisson-deviance pseudo-R^2 of Cameron and Windmeijer (1996). LM is the regression-based, heteroskedastic-robust Lagrange multiplier test of endogeneity of Wooldridge (1997) for the case of the Poisson $PMLE$ and the regression-based, heteroskedastic-robust Lagrange multiplier test of endogeneity of Wooldridge (1995) for linear regressions. LM is asymptotically distributed as a χ^2 with 2 degrees of freedom under the null hypothesis of joint exogeneity of AP_{peak} and $\text{AP}_{\text{off-peak}}$. The corresponding p-values are shown in brackets. Sample includes 1,004 observations for the incumbent and 989 for the entrant.

All regressions include sixteen time (quarter) and one hundred and eleven market (city) fixed effects. In general, these (non-reported) results are significant. I only report YEAR92 to document pricing differences once the market has settled. The first column presents the results of a pseudo-maximum likelihood count data regression model to evaluate the change in the number of foggy options offered during monopoly and competition. The other two columns are ordinary least square regressions to evaluate the impact of competition on deceptive pricing and tariff complexity, respectively. In computing all fogginess measures for this section, it is assumed that consumers are certain about future telephone usage at the time of signing up for one optional tariff plan. I will address the role of uncertainty regarding future individual telephone usage in Section 5.

Results indicate that the total number of foggy options offered by competing firms does not differ significantly from the number of foggy options offered by the incumbent during the monopoly phase. However, when considering any of the other two measures of pricing behavior, ϕ_1 or ϕ_2, it is clear that incumbents and entrants followed differentiated strategies when they competed. Consider tariff fogginess as measured by ϕ_1, the ratio of dominated to non-dominated tariffs offered by a firm. Compared to the fogginess of the tariffs offered by the incumbent during the monopoly phase, incumbent firms increase the use of deceptive options in a competitive environment while entrants reduce its use by an almost identical magnitude. Thus, entrants are responsible for making pricing less foggy, but since firms follow opposite strategies, we cannot conclude that competition solves the problem of deceptive tactics. However, deception does not appear to be the necessary consequence of competition, as we cannot argue that the transition to competition makes foggy pricing the default strategy of all firms. Finally, as for the complexity of the tariff lower envelope (ϕ_2), the incumbent appears to offer a more complex menu of tariff options to consumers while the entrant offers simpler tariffs, not very different from those offered by the incumbent during the monopoly phase. Simplicity and transparency appear to be the distinctive features of the pricing strategies of entrants, something that coincides with the anecdotal evidence available.[11] Interestingly, however, entrants appear to offer more complex (but not more deceptive) tariffs over time, as the sign of the estimate of YEAR92 indicates in the third column at the bottom of Table 4.

Results also indicate that deceptive or complex pricing by the incumbent does not respond significantly to consumers' usage heterogeneity as measured by the concavity of firms' own tariff lower envelope. The opposite is true for entrant firms. If consumers were very similar, the optimal nonlinear tariff would almost surely be a simple two-part tariff. Thus, the Arrow-Pratt measure of degree of concavity would approach zero. In general, it is in those cases when entrant firms offer more foggy options than the incumbent did, as seen by the significant negative estimate of AP_{peak}

[11] It is well documented that in the 1990s, established long distance telephone carriers such as AT&T or MCI competed by offering complex tariffs that discriminated in several dimensions, such as the distance of the call, time of the day, day of the week, *et cetera*. After Sprint entered this market, it offered a very successful strategy that bundled most of these pricing dimensions into a simple, easy to comprehend tariff: "Ten Cents a Minute." The result was that Sprint increased its market share at the expense of the other competitors and established itself as one of the large carriers in long distance telephony. See Knittel (1997).

in the ϕ_1 equation. This result indicates that the use of deceptive strategies by adding another effective tariff option to further segment the market leads to a very low increase in expected profits for entrants. If consumers are indeed heterogeneous, they offer more powerful mechanisms (positive estimate of AP_{peak} in the ϕ_2 equation) rather than more deceptive ones (negative estimate of AP_{peak} in the ϕ_1 equation).

4.1 Dynamic Competition Effects

The effect of competition on pricing might not be instantaneous. Cellular carriers had to be operating within six months of being awarded the license. Thus, the incumbent may anticipate the effect of entry of the second firm by offering a more or less foggy set of options in order to sign up as many customers as possible and lock them in its network before facing competition.[12] Similarly, along the lines of the popular "animality arguments" of Fudenberg and Tirole (1984), the incumbent and the entrant may delay changing their pricing tactics in order to accommodate or fight the entrant through pricing tactics that might make tariffs more or less transparent.

In order to uncover these dynamic effects of competition, I compute the dynamic treatment estimator of Laporte and Windmeijer (2005). To distinguish the short from the long effect of entry on foggy pricing, I define seven dummy variables for seven consecutive quarters. $\text{TREAT}(0)=1$ indicates the quarter when the second firm enters the industry. $\text{TREAT}(+1)=1$ indicates the quarter after the entry of the second competitor. All other dynamic dummies are defined in a similar manner. I consider the six quarters after the entry of the second firm. I do not include dummies for quarters during the monopoly phase. $\text{TREAT}(\geq+6)=1$ identifies the sixth quarter after the entry of the second carrier and all quarters thereafter. Thus, $\text{TREAT}(\geq+6)$ captures the long term effect of competition. Results are robust if I increase the number of quarters considered.

[12] In a recent work, Goolsbee and Syverson (2008) pointed out the relevance of this anticipatory argument when analyzing the common pricing strategies of the airline industry.

Table 5: Fogginess – Dynamic Treatment Effects

INCUMBENT	ϕ_0 $(PMLE)$		ϕ_1 (OLS)		ϕ_2 (OLS)	
YEAR92	0.0099	(0.82)	−0.0042	(0.08)	0.1888	(2.13)
TREAT(0)	0.0052	(0.77)	0.0358	(1.38)	0.1425	(3.51)
TREAT(+1)	0.0096	(1.70)	0.0503	(1.77)	0.0955	(2.19)
TREAT(+2)	0.0099	(1.82)	0.0621	(2.25)	0.0733	(1.83)
TREAT(+3)	0.0099	(1.78)	0.0493	(1.97)	0.0817	(1.98)
TREAT(+4)	0.0050	(0.77)	0.0394	(1.29)	0.0761	(1.60)
TREAT(+5)	0.0142	(2.17)	0.0788	(2.48)	0.0385	(0.93)
TREAT(≥+6)	0.0125	(1.76)	0.0675	(2.15)	0.0289	(0.62)
AP_{peak}	0.0090	(1.84)	0.0077	(0.19)	0.0192	(0.34)
$\text{AP}_{\text{off-peak}}$	0.0000	(1.05)	0.0000	(0.16)	−0.0004	(3.29)
$DPLRI$/ $Adj. R^2$	0.5974		0.6802		0.6833	
LM(Joint Test)	3.6038	[0.1650]	0.4290	[0.5125]	0.0001	[0.9918]
ENTRANT	ϕ_0 $(PMLE)$		ϕ_1 (OLS)		ϕ_2 (OLS)	
YEAR92	−0.0066	(1.27)	−0.0534	(1.22)	0.4073	(4.12)
TREAT(0)	0.0005	(0.18)	−0.0486	(1.88)	0.0469	(1.21)
TREAT(+1)	−0.0001	(0.05)	−0.0365	(1.17)	−0.0030	(0.06)
TREAT(+2)	0.0006	(0.20)	−0.0276	(0.97)	−0.0026	(0.05)
TREAT(+3)	0.0004	(0.14)	−0.0285	(1.01)	0.0110	(0.24)
TREAT(+4)	−0.0012	(0.39)	−0.0474	(1.64)	0.0625	(1.26)
TREAT(+5)	0.0018	(0.59)	−0.0291	(1.13)	0.0657	(1.27)
TREAT(≥+6)	0.0044	(1.32)	−0.0112	(0.38)	0.0359	(0.60)
AP_{peak}	−0.0015	(3.35)	−0.0141	(2.50)	0.0137	(2.10)
$\text{AP}_{\text{off-peak}}$	−0.0000	(0.89)	−0.0001	(0.03)	0.0003	(0.03)
$DPLRI$/ $Adj. R^2$	0.6419		0.6951		0.6575	
LM(Joint Test)	2.0338	[0.3617]	2.0295	[0.1543]	1.5502	[0.2131]

Dynamic treatment effects estimator of Laporte and Windmeijer (2005). Marginal effects evaluated at the sample mean of regressors and absolute, heteroskedastic-consistent t-statistics are reported in parentheses. $DPLRI$ is the Poisson-deviance pseudo-R^2 of Cameron and Windmeijer (1996). LM is the regression-based, heteroskedastic-robust Lagrange multiplier test of endogeneity of Wooldridge (1997) for the case of the Poisson $PMLE$ and the regression-based, heteroskedastic-robust Lagrange multiplier test of endogeneity of Wooldridge (1995) for linear regressions. LM is asymptotically distributed as a χ^2 with 2 degrees of freedom under the null hypothesis of joint exogeneity of AP_{peak} and $\text{AP}_{\text{off-peak}}$. The corresponding p-values are shown in brackets. Sample includes 1,004 observations for the incumbent and 989 for the entrant.

Table 5 repeats the analysis of Table 4, but with dynamic treatment effects to identify the transition from monopoly to competition. The LM test of endogeneity cannot reject the hypothesis that AP_{peak} and $\text{AP}_{\text{off-peak}}$ are jointly exogenous and estimates of AP_{peak}, $\text{AP}_{\text{off-peak}}$, and YEAR92 are very close to those reported in Table 4. The most interesting results though refer to the different magnitude of treatment effects as time elapses from the entry of the second firm. These dynamic treatment effects are represented in Figures 5 to 7 of the Online Appendix.

For the most part, incumbents offer the same number of foggy options (ϕ_0) before and after the entry of the second carrier. Entrants offer a number of foggy options that is consistently similar to the strategy of incumbents during the monopoly phase of these markets. Incumbents increase tariff fogginess (ϕ_1) significantly, but not until six months after the entry of the second cellular carrier. Entrants, on the contrary, reduce the fogginess of tariffs immediately when they enter. However, as time goes by, the fogginess of their tariffs becomes more similar to that of incumbents during monopoly. As for tariff complexity (ϕ_2), entrants consistently offer tariffs that are similar to pricing of incumbents during monopoly. The behavior of incumbents is, however, more interesting. Right after entry, they increase the complexity of their tariffs. But as time goes by, that increase in complexity stops being significant. Thus, competition triggers tariffs to become simpler, just as predicted by theoretical models of nonlinear pricing competition, such as Armstrong and Vickers (2001) or Rochet and Stole (2002). Nevertheless, this process takes a long time to materialize and there is no conclusive evidence that tariffs become simpler across competitors.[13]

One possibility that could call into question the validity of most results reported thus far is that the incumbent might preempt the entry of the second carrier by adjusting its pricing strategy prior to the entry in order to sign up as many consumers as possible before the second firm actually enters. Focusing on the incumbent behavior, results of Table 6 in the Online Appendix do not substantially vary their pricing tactics relative to their pricing a year and a half before entry of the second competitor.Thus, all previous results remain valid and document a differentiated behavior of incumbent and entrant firms regarding tariff fogginess and complexity.

[13] Table 7 in the Online Appendix report instrumental regressions that make use of the panel data structure of the data to construct valid instruments as in Hausman, Leonard and Zona (1994) and Hausman (1996). I use the last three variables of Table 3, AVGLEAD, AVGSHAREFOGGY, and AVGCOMPLEXITY, as instruments for AP_{peak} and $\text{AP}_{\text{off-peak}}$. Firms i and j may compete in several markets. Then, when analyzing the pricing of firm i, AVGLEADdenotes the average length in months of the monopoly phase in those markets. The other instruments, AVGSHAREFOGGY, and AVGCOMPLEXITY denote the average share of foggy options and the average degree of complexity of the tariff lower envelope, respectively. They always refer to the tariffs offered in the past by the competing firm j in the other markets where i and j currently compete against each other. The LM overidentifying restriction test indicates that these variables are in general good instruments. In all but one case in Tables 4, 5, and 6, the LM test of endogeneity fails to reject the null hypothesis of exogeneity of AP_{peak} and $\text{AP}_{\text{off-peak}}$.

5 Robustness to Heterogeneity in Usage and Uncertainty

The data used in this paper is very rich with details of the different tariff plans offered by the competing firms in different markets and for a reasonably long time span. Unfortunately, it does not contain any information on individual usage or tariff subscription. However, since computing the fogginess measures requires assuming some distribution of usage across the different usage profiles, it is possible to test whether results are robust to different assumed distributions of consumer heterogeneity regarding cellular telephone usage. Hence, I repeat the analysis assuming that cellular phone usage is distributed according to beta distributions $\beta(4\kappa/21, \kappa)$ for $\kappa = 1, 2, \ldots, 5$ on the 0-1000 minutes support. As κ increases, the variance of usage decreases while the mean of 160 monthly minutes of usage, representative of this early market, remains unaltered. All results of this section are reported in the Online Appendix.

Table 8 reports the effect of the most critical variables of the analysis after recomputing fogginess measures for different values of κ. For the variable DUOPOLY, the first line corresponds to the estimates of the average effects in Table 4. For the remaining variables, the first line corresponds to Table 5. Results of Table 8 confirm all results of Section 4, and in particular, that incumbent and entrant firms follow opposite strategies regarding fogginess and complexity during the duopoly phase of the market, even once we control for different distributions of telephone use.

The analysis of Section 4 was carried out under the assumption that cellular phone users knew exactly how much they were going to call each month. Varying κ affects the weight given to each usage profile, but it does not allow for individual uncertainty about future telephone usage at the time of signing up for a particular tariff option. However, consumers do not choose tariff options and telephone usage simultaneously in real life. Instead, consumers first choose a tariff option and later decide how much to talk on the phone. Choosing a particular tariff option does not force consumers to commit to any particular level of usage. The analysis of Section 4 thus remains valid if consumers' predictions are accurate.

For the analysis of Tables 4 and 5 in Section 4, I first determined which tariff option was the least expensive out of the 501,501 potential usage profiles defined by the combinations (a, b), where $a = 0, 1, 2, \ldots, 1000$ represented the number of peak minutes a household uses during a month, $b = 0, 1, 2, \ldots, 1000$ were the corresponding off-peak minutes of usage, and $a + b \leq 1000$. For the complexity measure, ϕ_2, it was assumed that usage was distributed according to a beta distribution, $\beta(4/21, 1)$, so that the average usage profile was 160 minutes a month, a magnitude that is representative of the monthly usage during this early market. This distribution captures the basic features of empirical telephone usage, as it puts more weight on low usage profiles and has a long right tail, thus making very intensive profiles a very infrequent event.

In the absence of individual subscription and usage data, I evaluate the robustness of the results of Section 4 to the existence of individual uncertainty regarding future usage by means of simulations. In order to capture the existence of future usage uncertainty among consumers, I identify which option leads to the lowest *expected* tariff payment when the realized consumption profile can be understood as a random draw from a particular bivariate normal distribution centered around (μ_a, μ_b), truncated at zero, and such that $\mu_a + \mu_b \leq 1000$. Thus, μ_a and μ_b represent the expected total duration of peak and off-peak calls, respectively, made by a household in a month. Usage in these two dimensions are assumed to be independently distributed according to univariate normal distributions with standard deviations proportional to the mean, *i.e.*, $\sigma_a = \tau\mu_a$ and $\sigma_b = \tau\mu_b$. This heteroskedasticy assumption captures the documented dispersion of telephone usage for different usage levels (*e.g.*, see Miravete (2005, §4)). For each of the 501,501 expected usage profiles defined by (μ_a, μ_b), I compute the expected payment under each tariff option by integrating out according to the assumed distributions of usage. Specifically, I compute the average payment of each tariff option over fifty random draws from $N[\mu_a, (\tau\mu_a)^2]$ for peak usage and another fifty from $N[\mu_b, (\tau\mu_b)^2]$ for off-peak usage.

Results are shown in Tables 9 and 10. Table 9 reports results analogous to Tables 4 and 5, but with the inclusion of uncertainty of future phone usage following the procedure just described. To further address the possibility of heterogeneity with regard to uncertainty, Table 9 also includes the case $\sigma = \sigma^\star$ where individuals are randomized from different $N[\mu_a, (\tau\mu_a)^2]$ and $N[\mu_b, (\tau\mu_b)^2]$ distributions.

Despite all these new considerations, Table 9 shows that most results of Section 4 (which are reported in the first line of each case) remain unchanged in the presence of uncertainty regarding future telephone usage at the time of subscription.[14] Considering individuals that are heterogeneous with respect to their uncertainty, *i.e.*, $\sigma = \sigma^\star$, has no distinguishable effect from those environments where the distribution of expected calls is very spread.

6 Concluding Remarks

To the best of my knowledge, this paper presents the first evaluation of firms' use of deceptive strategies, and most importantly, shows that competition does not necessarily foster their use through contract option proliferation or other practices aimed at deceiving heterogeneous consumers. I make use of a rich data set with detailed information on all tariff options offered by a multitude of cellular telephone companies before and after the entry of a second competitor. This information allows me to define and compute two measures of fogginess and a measure of tariff complexity to evaluate how competition may influence the use of deceptive and non-deceptive pricing strategies as entry of competing firms occurs exogenously in several local, independent markets.

[14] Combining consumers' usage heterogeneity and individual uncertainty, I could have forty different scenarios defined by five values of κ and eight values of σ. I estimated all these forty specifications. Results, which are available upon request, do not add anything significant to those reported in the Online Appendix. Summary statistics of many of these results are reported in Table 10.

Regarding the complexity of the lower envelope of the tariff, results only offer weak evidence supporting the predictions of theoretical models of nonlinear pricing. While entrants do not increase the complexity of the design of the tariff relative to the pricing behavior of incumbents during the monopoly phase, incumbents do. However, this change in tariff design is immediate upon entry of the second competitor and fades away as time elapses from that moment. This suggests that theoretical predictions —competition leads to less complex, flatter nonlinear tariffs— may hold after a sufficiently long period of time from entry has passed. Unfortunately, this does not unequivocally happen in the eighteen months after entry that the current analysis can afford evaluating.

The data also allows for a rich characterization of strategies for the case of fogginess of the menu of tariff options. The incumbent increases the ratio of dominated to non-dominated options six months after the entry of the second firm, while the entrant immediately reduces it by almost the same proportion. These opposite strategies survive even when we consider the possibility of individual uncertainty regarding future usage. For low levels of uncertainty, *i.e.*, when individuals are mostly accurate in predicting their future consumption, incumbents increase tariff fogginess and entrants do reduce it by the same amount. However, for high levels of uncertainty, incumbents increase the fogginess of their tariff offerings and entrants do not simplify it relative to the incumbent during the monopoly phase. Thus, the use of foggy pricing appears to be profitable only when consumers are very bad at predicting their future usage. However, in all cases, entrants always offer no more foggy tariffs than incumbent firms, so that the evidence does not support a widespread use of foggy pricing in competition relative to the monopoly phase of the market. All other results reported in the paper are robust to the existence of individual heterogeneity regarding uncertainty and usage of cellular telephone services.

References

Armstrong, Mark and John S. Vickers (2001) "Competitive Price Discrimination," *RAND Journal of Economics*, Vol. 32, No. 4, pp. 579–605.

Brandenburger, Adam M. and Barry J. Nalebuff (1996) *Co-opetition*, New York, NY: Doubleday.

Busse, Meghan R. and Marc Rysman (2005) "Competition and Price Discrimination in Yellow Pages Advertising," *RAND Journal of Economics*, Vol. 36, No. 2, pp. 378–390.

Cameron, A. Colin and Frank A. G. Windmeijer (1996) "R-Squared Measures for Count Data Regression Models with Applications to Health Care Utilization," *Journal of Business and Economic Statistics*, Vol. 14, No. 2, pp. 209–220.

Ellison, Glenn (2005) "A Model of Add-On Pricing," *Quarterly Journal of Economics*, Vol. 120, No. 2, pp. 585–637.

Ellison, Glenn and Sara Fisher Ellison (2009) "Search, Obfuscation, and Price Elasticities on the Internet," *Econometrica*, Vol. 77, No. 2, pp. 427–452.

Fudenberg, Drew and Jean Tirole (1984) "The Fat-Cat Effect, The Puppy-Dog Ploy and the Lean and Hungry Look," *American Economic Review (Papers and Proceedings)*, Vol. 74, No. 2, pp. 361–366.

Gabaix, Xavier and David Laibson (2006) "Shrouded Attributes, Consumer Myopia, and Information Supression in Competitive Markets," *Quarterly Journal of Economics*, Vol. 121, No. 2, pp. 505–540.

Goolsbee, Austan and Chad Syverson (2008) "How Do Incumbents Respond to the Threat of Entry? Evidence from the Major Airlines," *Quarterly Journal of Economics*, Vol. 123, No. 4, pp. 1611–1633.

Hausman, Jerry A. (1996) "Valuation of New Goods under Perfect and Imperfect Competition," in Timothy F. Bresnahan and Robert J. Gordon eds. *The Economics of New Goods,* Studies in Income and Wealth, Vol. 58, Chicago, IL: NBER–The University of Chicago Press.

——— (2002) "Mobile Telephone," in Martin E. Cave, Sumit K. Majumdar, and Ingo Vogelsang eds. *Handbook of Telecommunications Economics,* Vol. I, Amsterdam, The Netherlands: North-Holland.

Hausman, Jerry A., Gregory Leonard, and J Douglas. Zona (1994) "Competitive Analysis with Differentiated Products," *Annales d'Economie et de Statistique*, Vol. 34, No. 2, pp. 159–180.

Knittel, Christopher R. (1997) "Interstate Long Distance Rates: Search Costs, Switching Costs, and Market Power," *Review of Industrial Organization*, Vol. 12, No. 4, pp. 519–536.

Laporte, Audrey and Frank Windmeijer (2005) "Estimation of Panel Data Models with Binary Indicators when Treatment Effects Are Not Constant Over Time," *Economics Letters*, Vol. 88, No. 3, pp. 389–396.

Marciano, Sonia (2000) "Pricing Policies in Oligopoly with Product Differentiation: The Case of Cellular Telephony," Ph.D. Thesis, University of Chicago Graduate School of Business.

Maskin, Eric and John Riley (1984) "Monopoly with Incomplete Information," *RAND Journal of Economics*, Vol. 15, No. 2, pp. 171–196.

Miravete, Eugenio J. (2005) "The Welfare Performace of Sequential Pricing Mechanisms," *International Economic Review*, Vol. 46, No. 4, pp. 1321–1360.

——— (2011) "Convolution and Composition of Totally Positive Random Variables in Economics," *Journal of Mathematical Economics*, Vol. 47, p. forthcoming.

Murray, James B., Jr (2002) *Wireless Nation. The Frenzied Launch of the Cellular Revolution in America*, Cambridge, MA: Perseus Publishing.

Oi, Walter (1971) "A Disneyland Dilemma: Two-Part Tariffs for a Mickey Mouse Monopoly," *Quarterly Journal of Economic*, Vol. 85, No. 1, pp. 77–96.

Parker, Philip M. and Lars-Hendrik Röller (1997) "Collusive Conduct in Duopolies: Multimarket Contact and Cross-Ownership in the Mobile Telephone Industry," *RAND Journal of Economics*, Vol. 28, pp. 304–322.

Rochet, Jean-Charles and Lars A. Stole (2002) "Nonlinear Pricing with Random Participation," *The Review of Economic Studies*, Vol. 69, No. 1, pp. 277–311.

Spiegler, Ran (2011) *Bounded Rationality and Industrial Organization*, New York, NY: Oxford University Press.

Tirole, Jean (1989) *Industrial Organization*, Cambridge, MA: MIT Press.

Vogelsang, Ingo and Bridger M. Mitchell (1997) *Telecommunications Competition: The Last Ten Miles*, Cambridge, MA: AEI–MIT Press.

Wilson, Robert B. (1993) *Nonlinear Pricing*, New York, NY: Oxford University Press.

Wooldridge, Jeffrey M. (1995) "Score Diagnostics for Linear Models Estimated by Two Stage Least Squares," in Gangadharrao S. Maddala, Peter C. B. Phillips, and Thirukodikaval N. Srinivasan eds. *Advances in Econometrics and Quantitative Economics*, Oxford, UK: Blackwell.

——— (1997) "Quasi-Likelihood Methods for Count Data," in M. Hashem Pesaran and Peter Schmidt eds. *Handbook of Applied Econometrics,* Vol. 2, Oxford, UK: Blackwell.

Web Appendix

Competition and the Use of Foggy Pricing

Eugenio J. Miravete

Figure 4 illustrates this optimal nonlinear tariff for different values of λ. Figure 4 assumes a marginal cost $c = 1$ and an asymmetric distribution parameter $\lambda = 0$ for "Schedule A," $\lambda = 1$ for "Schedule B," and $\lambda = 2$ for "Schedule C." In all cases I normalize the reservation utility to $\underline{\mathcal{U}} = 0$. The optimality condition (3) translates into all nonlinear tariff schedules in Figure 4 having the same 45 degree slope at the maximum consumption level where the marginal tariff equals the marginal cost of production. Finally, notice that tariffs in Figure 4 do not cross each other as the hazard rate of the distribution is monotonically increasing in λ, *i.e.*, because parameter λ indexes distribution $F(\theta)$ with respect to a hazard rate ordering.

Figure 4: Asymmetry of Information and Curvature of Nonlinear Tariffs

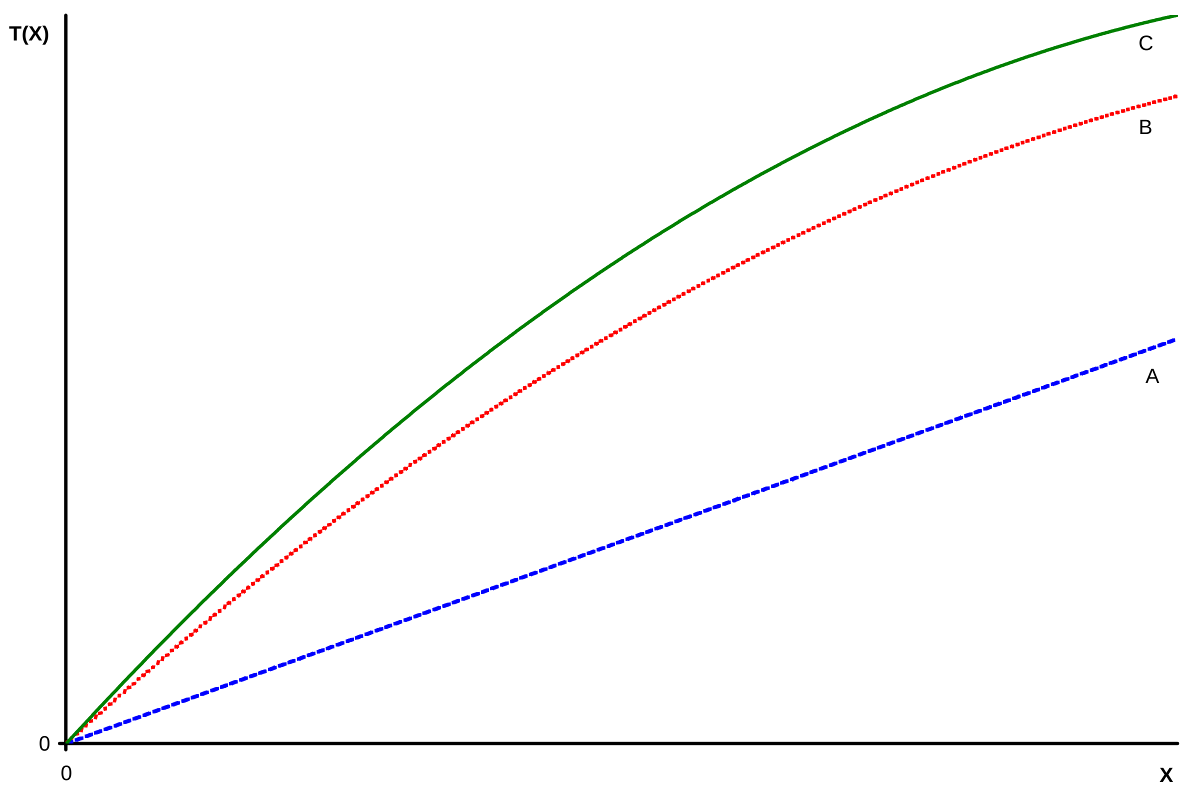


Figure 5: Dynamic Competition Effects on ϕ_0

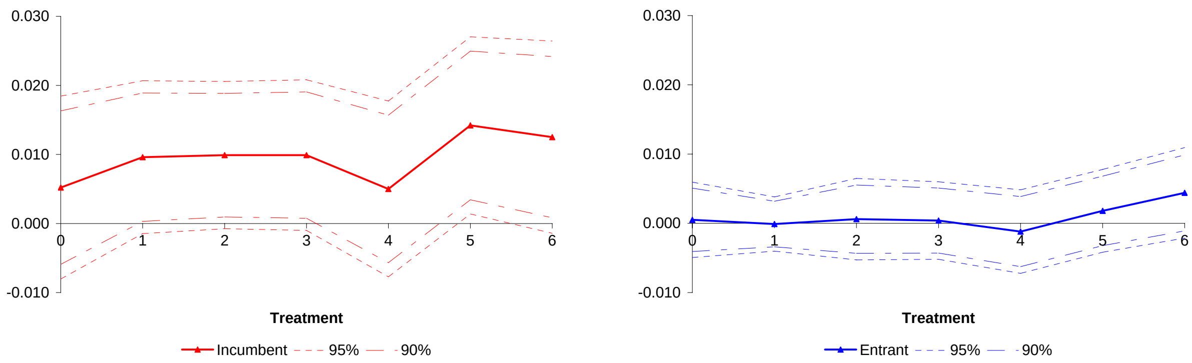


Figure 6: Dynamic Competition Effects on ϕ_1

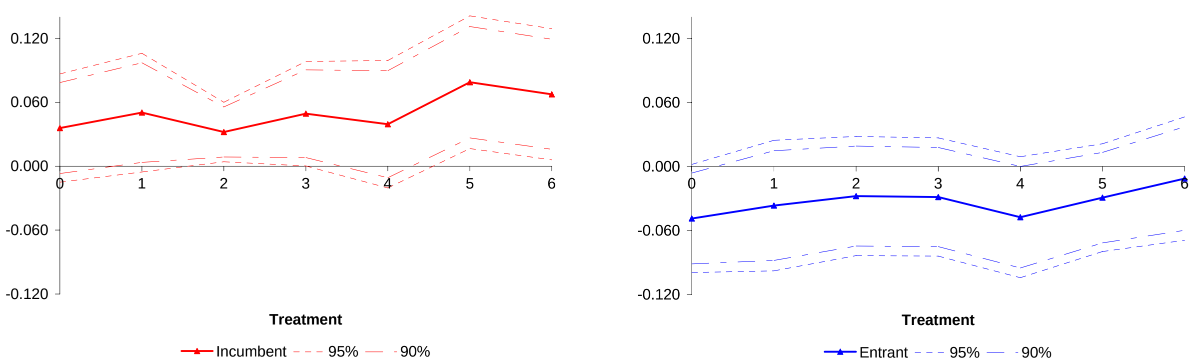


Figure 7: Dynamic Competition Effects on ϕ_2

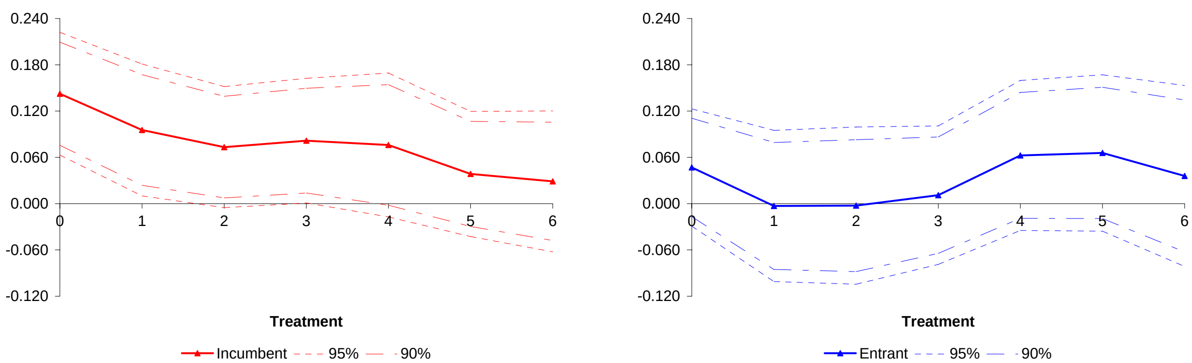


Table 6: Fogginess – Incumbent: Preemption

	ϕ_0 $(PMLE)$		ϕ_1 (OLS)		ϕ_2 (OLS)	
YEAR92	0.0075	(0.49)	−0.0218	(0.29)	0.1560	(1.32)
TREAT(−6)	−0.0004	(0.07)	0.0179	(0.74)	0.0874	(1.97)
TREAT(−5)	0.0066	(1.01)	0.0314	(1.14)	0.0124	(0.31)
TREAT(−4)	0.0029	(0.44)	0.0255	(0.81)	0.0342	(0.85)
TREAT(−3)	−0.0001	(0.01)	0.0062	(0.20)	0.0438	(0.95)
TREAT(−2)	0.0045	(0.60)	0.0216	(0.59)	0.0044	(0.09)
TREAT(−1)	0.0007	(0.10)	0.0063	(0.18)	0.0413	(0.79)
TREAT(0)	0.0075	(0.77)	0.0533	(1.26)	0.1796	(2.74)
TREAT(+1)	0.0125	(1.36)	0.0696	(1.47)	0.1306	(1.76)
TREAT(+2)	0.0126	(1.32)	0.0822	(1.66)	0.1097	(1.47)
TREAT(+3)	0.0124	(1.24)	0.0685	(1.40)	0.1247	(1.54)
TREAT(+4)	0.0081	(0.75)	0.0614	(1.10)	0.1184	(1.39)
TREAT(+5)	0.0172	(1.53)	0.1018	(1.73)	0.0852	(1.01)
TREAT(≥+6)	0.0159	(1.22)	0.0929	(1.38)	0.0795	(0.79)
AP_{peak}	0.0091	(1.87)	0.0084	(0.21)	0.0175	(0.32)
$\text{AP}_{\text{off-peak}}$	0.0000	(1.04)	0.0000	(0.14)	−0.0004	(3.28)
$DPLRI/$ $Adj.R^2$	0.5977		0.6788		0.6830	
LM(Joint Test)	1.6425	[0.4399]	1.0007	[0.3171]	0.0181	[0.8929]

Marginal effects evaluated at the sample mean of regressors and absolute, heteroskedastic-consistent t-statistics are reported in parentheses. $DPLRI$ is the Poisson-deviance pseudo-R^2 of Cameron and Windmeijer (1996). LM is the regression-based, heteroskedastic-robust Lagrange multiplier test of endogeneity of Wooldridge (1997) for the case of the Poisson $PMLE$ and the regression-based, heteroskedastic-robust Lagrange multiplier test of endogeneity of Wooldridge (1995) for linear regressions. LM is asymptotically distributed as a χ^2 with 2 degrees of freedom under the null hypothesis of joint exogeneityof AP_{peak} and $\text{AP}_{\text{off-peak}}$. The corresponding p-values are shown in brackets. Sample includes 1004 observations.

Figure 8: Preemptive Effects on ϕ_2

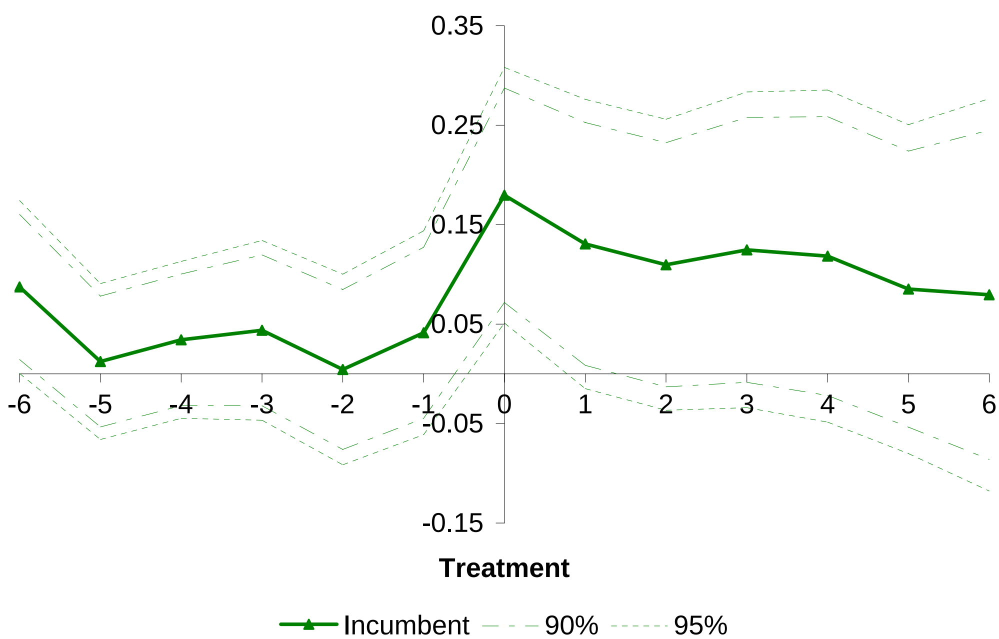


Table 7: Instrumental Regressions

	Table 4				Table 5				Table 6			
	AP_{peak}		$AP_{off-peak}$		AP_{peak}		$AP_{off-peak}$		AP_{peak}		$AP_{off-peak}$	
YEAR92	−0.0033	(0.03)	12.7393	(1.27)	0.1482	(0.59)	5.4098	(1.18)				
DUOPOLY	0.0814	(1.25)	1.7590	(0.32)	−0.0134	(0.08)	−4.6994	(1.71)				
AVGLEAD	0.0210	(1.01)	2.2249	(1.62)	−0.0083	(0.24)	2.4152	(1.02)				
AVGSHAREFOGGY	−0.1946	(0.93)	2.6614	(0.05)	−0.3389	(0.49)	−33.1562	(0.95)				
AVGCOMPLEXITY	−0.0356	(0.47)	−40.6930	(1.33)	−0.1685	(0.56)	−12.8090	(1.06)				
Adj. R^2	0.1546		0.4909		0.3688		0.4620					
LM (Joint Test)	2.5883	[0.2741]	2.8212	[0.2440]	0.5457	[0.7612]	3.3668	[0.1857]				
YEAR92	−0.0480	(0.33)	30.1987	(2.26)	0.4672	(1.35)	6.5568	(1.18)	0.1551	(0.80)	22.5585	(1.37)
TREAT(−6)									−0.0264	(0.33)	9.9510	(1.21)
TREAT(−5)									−0.0408	(0.55)	9.4008	(1.28)
TREAT(−4)									−0.0508	(0.58)	8.6012	(1.28)
TREAT(−3)									−0.0465	(0.49)	7.5132	(1.07)
TREAT(−2)									−0.3636	(1.11)	5.3284	(0.76)
TREAT(−1)									−0.0616	(0.58)	4.7728	(0.59)
TREAT(0)	0.0224	(0.30)	−7.7382	(0.89)	−0.1945	(0.98)	−5.5946	(1.32)	−0.1002	(0.76)	−0.1934	(0.02)
TREAT(+1)	0.1822	(2.14)	7.2494	(0.66)	0.0677	(0.24)	−3.9223	(1.37)	0.0819	(0.66)	14.3184	(1.11)
TREAT(+2)	0.1988	(1.92)	6.5287	(0.50)	0.1091	(0.40)	−4.0705	(1.37)	0.0803	(0.56)	13.5652	(0.90)
TREAT(+3)	0.2356	(2.26)	6.4513	(0.54)	0.1224	(0.48)	−4.1455	(1.37)	0.1191	(0.82)	13.8442	(1.06)
TREAT(+4)	0.2253	(1.99)	−15.3911	(1.21)	−0.3179	(0.94)	−4.0808	(1.09)	0.0788	(0.50)	−7.5918	(0.71)
TREAT(+5)	0.2176	(2.05)	−15.5677	(1.24)	−0.3105	(0.89)	−4.1684	(1.17)	0.0824	(0.48)	−7.1958	(0.61)
TREAT(≥+6)	0.2183	(1.73)	−17.1922	(1.63)	−0.3424	(1.19)	−5.3253	(1.16)	0.0397	(0.18)	−7.6736	(0.73)
AVGLEAD	0.0065	(0.36)	2.4976	(1.51)	−0.0061	(0.20)	2.3241	(0.98)	0.0004	(0.02)	2.7399	(1.58)
AVGSHAREFOGGY	−0.3707	(1.41)	10.1510	(0.20)	−0.2305	(0.29)	−33.6756	(0.97)	−0.4151	(1.52)	11.7683	(0.22)
AVGCOMPLEXITY	−0.1027	(1.17)	−41.9350	(1.35)	−0.1996	(0.75)	−13.1949	(1.08)	−0.1092	(1.17)	−41.7008	(1.34)
Adj. R^2	0.1520		0.4946		0.3710		0.4583		0.1627		0.4919	
LM (Joint Test)	2.8570	[0.2400]	2.3876	[0.3031]	0.8963	[0.6388]	3.1478	[0.2072]	2.8048	[0.2460]	1.8950	[0.3877]

OLS estimates. Absolute, heteroskedastic-consistent t-statistics are presented in parentheses. All regressions also include time (quarter) and market (city) fixed effects, although these estimates are not reported. *LM* is the regression-based, heteroskedastic-robust overidentification restriction test of Wooldridge (1995). *LM* is asymptotically distributed as a χ^2 distribution with 3 degrees of freedom under the null hypothesis of joint validity of the instruments. Its p-value is shown in brackets.

Table 8: Heterogeneity of Usage Patterns: Alternative Distributions

	INCUMBENT (Table 4)						*ENTRANT* (Table 4)					
DUOPOLY	ϕ_0 (*PMLE*)		ϕ_1 (*OLS*)		ϕ_2 (*OLS*)		ϕ_0 (*PMLE*)		ϕ_1 (*OLS*)		ϕ_2 (*OLS*)	
$\beta(4/21,1)$	0.0069	(1.42)	0.0437	(2.25)	0.1159	(3.42)	−0.0006	(0.27)	−0.0440	(2.12)	0.0261	(0.72)
$\beta(8/21,2)$	0.0069	(1.42)	0.0437	(2.25)	0.1204	(3.67)	−0.0006	(0.27)	−0.0440	(2.12)	0.0004	(0.01)
$\beta(12/21,3)$	0.0069	(1.42)	0.0437	(2.25)	0.1231	(3.77)	−0.0006	(0.27)	−0.0440	(2.12)	−0.0120	(0.34)
$\beta(16/21,4)$	0.0069	(1.42)	0.0437	(2.25)	0.1250	(3.81)	−0.0006	(0.27)	−0.0440	(2.12)	−0.0180	(0.51)
$\beta(20/21,5)$	0.0069	(1.42)	0.0437	(2.25)	0.1264	(3.83)	−0.0006	(0.27)	−0.0440	(2.12)	−0.0212	(0.60)
	INCUMBENT (Table 5)						*ENTRANT* (Table 5)					
YEAR92	ϕ_0 (*PMLE*)		ϕ_1 (*OLS*)		ϕ_2 (*OLS*)		ϕ_0 (*PMLE*)		ϕ_1 (*OLS*)		ϕ_2 (*OLS*)	
$\beta(4/21,1)$	0.0099	(0.82)	−0.0042	(0.08)	0.0188	(2.13)	−0.0066	(1.27)	−0.0534	(1.22)	0.4073	(4.12)
$\beta(8/21,2)$	0.0099	(0.82)	−0.0042	(0.08)	0.1795	(2.04)	−0.0066	(1.27)	−0.0534	(1.22)	0.3800	(3.88)
$\beta(12/21,3)$	0.0099	(0.82)	−0.0042	(0.08)	0.1816	(2.07)	−0.0066	(1.27)	−0.0534	(1.22)	0.3786	(3.83)
$\beta(16/21,4)$	0.0099	(0.82)	−0.0042	(0.08)	0.1828	(2.08)	−0.0066	(1.27)	−0.0534	(1.22)	0.3831	(3.84)
$\beta(20/21,5)$	0.0099	(0.82)	−0.0042	(0.08)	0.1836	(2.08)	−0.0066	(1.27)	−0.0534	(1.22)	0.3884	(3.87)
TREAT(0)	ϕ_0 (*PMLE*)		ϕ_1 (*OLS*)		ϕ_2 (*OLS*)		ϕ_0 (*PMLE*)		ϕ_1 (*OLS*)		ϕ_2 (*OLS*)	
$\beta(4/21,1)$	0.0052	(0.77)	0.0358	(1.38)	0.1425	(3.51)	0.0005	(0.18)	−0.0486	(1.88)	0.0469	(1.21)
$\beta(8/21,2)$	0.0052	(0.77)	0.0358	(1.38)	0.1500	(3.68)	0.0005	(0.18)	−0.0486	(1.88)	0.0136	(0.35)
$\beta(12/21,3)$	0.0052	(0.77)	0.0358	(1.38)	0.1536	(3.73)	0.0005	(0.18)	−0.0486	(1.88)	−0.0005	(0.01)
$\beta(16/21,4)$	0.0052	(0.77)	0.0358	(1.38)	0.1557	(3.76)	0.0005	(0.18)	−0.0486	(1.88)	−0.0064	(0.16)
$\beta(20/21,5)$	0.0052	(0.77)	0.0358	(1.38)	0.1572	(3.77)	0.0005	(0.18)	−0.0486	(1.88)	−0.0091	(0.23)
TREAT(+1)	ϕ_0 (*PMLE*)		ϕ_1 (*OLS*)		ϕ_2 (*OLS*)		ϕ_0 (*PMLE*)		ϕ_1 (*OLS*)		ϕ_2 (*OLS*)	
$\beta(4/21,1)$	0.0096	(1.70)	0.0503	(1.77)	0.0955	(2.19)	−0.0001	(0.05)	−0.0365	(1.17)	−0.0030	(0.06)
$\beta(8/21,2)$	0.0096	(1.70)	0.0503	(1.77)	0.0961	(2.31)	−0.0001	(0.05)	−0.0365	(1.17)	−0.0265	(0.57)
$\beta(12/21,3)$	0.0096	(1.70)	0.0503	(1.77)	0.0976	(2.36)	−0.0001	(0.05)	−0.0365	(1.17)	−0.0384	(0.82)
$\beta(16/21,4)$	0.0096	(1.70)	0.0503	(1.77)	0.0992	(2.40)	−0.0001	(0.05)	−0.0365	(1.17)	−0.0446	(0.95)
$\beta(20/21,5)$	0.0096	(1.70)	0.0503	(1.77)	0.1007	(2.42)	−0.0001	(0.05)	−0.0365	(1.17)	−0.0481	(1.03)
TREAT($\geq$+6)	ϕ_0 (*PMLE*)		ϕ_1 (*OLS*)		ϕ_2 (*OLS*)		ϕ_0 (*PMLE*)		ϕ_1 (*OLS*)		ϕ_2 (*OLS*)	
$\beta(4/21,1)$	0.0125	(1.76)	0.0675	(2.15)	0.0289	(0.62)	0.0044	(1.32)	−0.0112	(0.38)	0.0359	(0.60)
$\beta(8/21,2)$	0.0125	(1.76)	0.0675	(2.15)	0.0312	(0.68)	0.0044	(1.32)	−0.0112	(0.38)	0.0168	(0.28)
$\beta(12/21,3)$	0.0125	(1.76)	0.0675	(2.15)	0.0330	(0.72)	0.0044	(1.32)	−0.0112	(0.38)	0.0081	(0.13)
$\beta(16/21,4)$	0.0125	(1.76)	0.0675	(2.15)	0.0352	(0.76)	0.0044	(1.32)	−0.0112	(0.38)	0.0040	(0.07)
$\beta(20/21,5)$	0.0125	(1.76)	0.0675	(2.15)	0.0370	(0.80)	0.0044	(1.32)	−0.0112	(0.38)	0.0021	(0.03)

Marginal effects evaluated at the sample mean of regressors for samples with alternative assumed distributions of usage in the absence of uncertainty, *i.e.*, for $\sigma = 0$. Absolute, heteroskedasticy-consistent t-statistics are reported in parentheses. DUOPOLY refers to the regression with a single average treatment effect, while the remaining variables refer to the regression that includes dynamic treatments.

Table 9: Fogginess and Uncertainty: Dominated and Non-Dominated Tariff Options

	INCUMBENT (Table 4)			*ENTRANT* (Table 4)		
DUOPOLY	ϕ_0 $(PMLE)$	ϕ_1 (OLS)	ϕ_2 (OLS)	ϕ_0 $(PMLE)$	ϕ_1 (OLS)	ϕ_2 (OLS)
$\sigma = 0.00\mu$	0.0069 (1.42)	0.0437 (2.25)	0.1159 (3.42)	−0.0006 (0.27)	−0.0440 (2.12)	0.0261 (0.72)
$\sigma = 0.10\mu$	0.0063 (1.33)	0.0323 (1.57)	0.1283 (3.83)	−0.0002 (0.10)	−0.0382 (1.87)	0.0051 (0.14)
$\sigma = 0.25\mu$	0.0059 (1.24)	0.0313 (1.51)	0.1355 (4.05)	−0.0002 (0.09)	−0.0375 (1.85)	0.0006 (0.02)
$\sigma = 0.50\mu$	0.0066 (1.37)	0.0324 (1.57)	0.1318 (3.80)	−0.0006 (0.29)	−0.0401 (2.04)	0.0235 (0.66)
$\sigma = 1.00\mu$	0.0103 (2.07)	0.0397 (2.00)	0.1099 (3.11)	−0.0016 (1.11)	−0.0292 (1.52)	0.0137 (0.38)
$\sigma = 1.50\mu$	0.0054 (1.54)	0.0298 (1.62)	0.1280 (3.57)	−0.0019 (0.87)	−0.0222 (1.12)	0.0257 (0.72)
$\sigma = 2.25\mu$	0.0045 (1.30)	0.0276 (1.50)	0.1339 (4.16)	−0.0004 (0.10)	−0.0253 (1.20)	0.0031 (0.09)
$\sigma = 3.00\mu$	0.0134 (1.36)	0.0330 (1.80)	0.1267 (4.04)	0.0061 (0.93)	−0.0152 (0.70)	−0.0528 (1.49)
$\sigma = \sigma^\star$	0.0040 (1.45)	0.0317 (1.60)	0.1229 (3.47)	−0.0028 (1.12)	−0.0301 (1.32)	0.0421 (1.15)
	INCUMBENT (Table 5)			*ENTRANT* (Table 5)		
YEAR92	ϕ_0 $(PMLE)$	ϕ_1 (OLS)	ϕ_2 (OLS)	ϕ_0 $(PMLE)$	ϕ_1 (OLS)	ϕ_2 (OLS)
$\sigma = 0.00\mu$	0.0099 (0.82)	−0.0042 (0.08)	0.0188 (2.13)	−0.0066 (1.27)	−0.0534 (1.22)	0.4073 (4.12)
$\sigma = 0.10\mu$	0.0126 (1.03)	0.0305 (0.54)	0.1598 (1.80)	−0.0063 (1.17)	−0.0387 (0.77)	0.4125 (4.05)
$\sigma = 0.25\mu$	0.0115 (0.94)	0.0270 (0.47)	0.1543 (3.88)	−0.0062 (1.15)	−0.0370 (0.74)	0.4223 (4.20)
$\sigma = 0.50\mu$	0.0113 (0.94)	0.0267 (0.46)	0.1874 (2.00)	−0.0037 (0.79)	−0.0198 (0.40)	0.3646 (3.47)
$\sigma = 1.00\mu$	0.0021 (0.18)	0.0040 (0.07)	0.2393 (2.69)	−0.0021 (0.67)	−0.0221 (0.42)	0.3919 (3.60)
$\sigma = 1.50\mu$	0.0061 (0.68)	0.0265 (0.45)	0.2190 (2.48)	−0.0034 (0.71)	−0.0274 (0.55)	0.3840 (3.50)
$\sigma = 2.25\mu$	0.0061 (0.68)	0.0207 (0.37)	0.1840 (2.16)	−0.0118 (1.38)	−0.0493 (1.01)	0.4827 (4.74)
$\sigma = 3.00\mu$	0.0216 (0.85)	0.0256 (0.46)	0.1380 (1.67)	−0.0154 (1.06)	−0.0315 (0.63)	0.4493 (4.50)
$\sigma = \sigma^\star$	0.0015 (0.24)	−0.0032 (0.06)	0.1570 (1.88)	−0.0073 (1.55)	−0.0574 (1.44)	0.3502 (3.44)
TREAT(0)	ϕ_0 $(PMLE)$	ϕ_1 (OLS)	ϕ_2 (OLS)	ϕ_0 $(PMLE)$	ϕ_1 (OLS)	ϕ_2 (OLS)
$\sigma = 0.00\mu$	0.0052 (0.77)	0.0358 (1.38)	0.1425 (3.51)	0.0005 (0.18)	−0.0486 (1.88)	0.0469 (1.21)
$\sigma = 0.10\mu$	0.0057 (0.88)	0.0285 (1.07)	0.1465 (3.68)	0.0012 (0.41)	−0.0404 (1.56)	0.0238 (0.62)
$\sigma = 0.25\mu$	0.0052 (0.80)	0.0278 (1.04)	0.1238 (2.76)	0.0011 (0.37)	−0.0408 (1.58)	0.0248 (0.64)
$\sigma = 0.50\mu$	0.0072 (1.11)	0.0344 (1.31)	0.1375 (3.35)	0.0007 (0.24)	−0.0418 (1.68)	0.0477 (1.21)
$\sigma = 1.00\mu$	0.0106 (1.56)	0.0395 (1.56)	0.1180 (2.90)	−0.0009 (0.51)	−0.0359 (1.43)	0.0472 (1.15)
$\sigma = 1.50\mu$	0.0051 (1.11)	0.0283 (1.20)	0.1465 (3.75)	−0.0013 (0.44)	−0.0363 (1.40)	0.0588 (1.43)
$\sigma = 2.25\mu$	0.0034 (0.73)	0.0207 (0.89)	0.1596 (4.46)	0.0015 (0.32)	−0.0367 (1.37)	0.0220 (0.57)
$\sigma = 3.00\mu$	0.0122 (0.94)	0.0274 (1.15)	0.1497 (4.16)	0.0086 (1.02)	−0.0305 (1.11)	−0.0170 (0.44)
$\sigma = \sigma^\star$	0.0040 (1.05)	0.0295 (1.08)	0.1508 (3.34)	−0.0028 (0.89)	−0.0402 (1.42)	0.0672 (1.56)
TREAT(+1)	ϕ_0 $(PMLE)$	ϕ_1 (OLS)	ϕ_2 (OLS)	ϕ_0 $(PMLE)$	ϕ_1 (OLS)	ϕ_2 (OLS)
$\sigma = 0.00\mu$	0.0096 (1.70)	0.0503 (1.77)	0.0955 (2.19)	−0.0001 (0.05)	−0.0365 (1.17)	−0.0030 (0.06)
$\sigma = 0.10\mu$	0.0072 (1.26)	0.0307 (1.02)	0.1209 (2.71)	0.0001 (0.04)	−0.0321 (1.03)	−0.0244 (0.52)
$\sigma = 0.25\mu$	0.0071 (1.24)	0.0302 (1.01)	0.0795 (1.84)	0.0003 (0.09)	−0.0308 (0.99)	−0.0320 (0.70)
$\sigma = 0.50\mu$	0.0096 (1.79)	0.0273 (0.90)	0.1160 (2.52)	−0.0005 (0.17)	−0.0356 (1.19)	−0.0021 (0.05)
$\sigma = 1.00\mu$	0.0119 (2.07)	0.0642 (2.25)	0.0900 (1.96)	−0.0013 (0.75)	−0.0204 (0.71)	−0.0160 (0.35)
$\sigma = 1.50\mu$	0.0073 (1.80)	0.0453 (1.72)	0.1016 (2.20)	−0.0016 (0.60)	−0.0115 (0.40)	0.0014 (0.03)
$\sigma = 2.25\mu$	0.0065 (1.64)	0.0427 (1.65)	0.1098 (2.40)	0.0004 (0.08)	−0.0147 (0.50)	−0.0253 (0.57)
$\sigma = 3.00\mu$	0.0183 (1.59)	0.0445 (1.67)	0.0980 (2.22)	0.0073 (0.91)	−0.0034 (0.11)	−0.0811 (1.73)
$\sigma = \sigma^\star$	0.0046 (1.28)	0.0370 (1.23)	0.0906 (1.92)	−0.0031 (0.97)	−0.0307 (1.07)	0.0209 (0.46)
TREAT(≥+6)	ϕ_0 $(PMLE)$	ϕ_1 (OLS)	ϕ_2 (OLS)	ϕ_0 $(PMLE)$	ϕ_1 (OLS)	ϕ_2 (OLS)
$\sigma = 0.00\mu$	0.0125 (1.76)	0.0675 (2.15)	0.0289 (0.62)	0.0044 (1.32)	−0.0112 (0.38)	0.0359 (0.60)
$\sigma = 0.10\mu$	0.0109 (1.55)	0.0419 (1.19)	0.0523 (1.16)	0.0053 (1.55)	−0.0039 (0.14)	0.0113 (0.20)
$\sigma = 0.25\mu$	0.0108 (1.53)	0.0413 (1.18)	0.0514 (1.13)	0.0023 (0.74)	−0.0067 (0.23)	0.0194 (0.34)
$\sigma = 0.50\mu$	0.0119 (1.70)	0.0496 (1.40)	0.0427 (0.89)	0.0039 (1.27)	−0.0102 (0.38)	0.0623 (1.10)
$\sigma = 1.00\mu$	0.0163 (2.27)	0.0563 (1.68)	0.0089 (0.18)	0.0013 (0.61)	−0.0066 (0.23)	0.0517 (0.93)
$\sigma = 1.50\mu$	0.0067 (1.29)	0.0300 (0.92)	0.0658 (1.27)	0.0028 (0.87)	0.0046 (0.16)	0.0519 (0.93)
$\sigma = 2.25\mu$	0.0055 (1.05)	0.0232 (0.74)	0.0873 (1.81)	0.0101 (1.81)	0.0105 (0.34)	−0.0382 (0.67)
$\sigma = 3.00\mu$	0.0160 (1.03)	0.0240 (0.71)	0.0922 (1.98)	0.0228 (2.38)	0.0202 (0.63)	−0.0658 (1.17)
$\sigma = \sigma^\star$	0.0059 (1.42)	0.0367 (1.27)	0.0738 (1.59)	0.0027 (0.71)	0.0043 (0.15)	0.0948 (1.76)

Marginal effects evaluated at the sample mean of regressors for samples with alternative assumed distributions of usage uncertainty and when telephone usage is distributed according to a beta distribution $\beta(4/21, 1)$ on the 0-1000 monthly minute range. Absolute, heteroskedastic-consistent t-statistics are reported in parentheses.

Table 10: Fogginess and Uncertainty: Measures of Fogginess (Duopoly Phase)

	INCUMBENT						*ENTRANT*					
	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
Beta(4/21,1)	ϕ_0		ϕ_1		ϕ_2		ϕ_0		ϕ_1		ϕ_2	
$\sigma = 0.00\mu$	1.5893	(1.0526)	0.4078	(0.2219)	0.6886	(0.5704)	1.4960	(1.2336)	0.3722	(0.2633)	0.5894	(0.5968)
$\sigma = 0.10\mu$	1.5624	(1.0708)	0.3697	(0.2287)	0.7310	(0.5736)	1.5079	(1.2527)	0.3742	(0.2648)	0.5925	(0.6141)
$\sigma = 0.25\mu$	1.5566	(1.0711)	0.3950	(0.2282)	0.7358	(0.5690)	1.4941	(1.2411)	0.3697	(0.2624)	0.6079	(0.6093)
$\sigma = 0.50\mu$	1.5374	(1.0755)	0.3889	(0.2287)	0.7570	(0.5689)	1.4289	(1.2412)	0.3488	(0.2497)	0.6755	(0.6005)
$\sigma = 1.00\mu$	1.5624	(1.1009)	0.3931	(0.2294)	0.7356	(0.5254)	1.3458	(1.1067)	0.3356	(0.2353)	0.7693	(0.7682)
$\sigma = 1.50\mu$	1.5029	(1.1234)	0.3724	(0.2291)	0.7900	(0.5317)	1.3656	(1.1021)	0.3407	(0.2338)	0.7632	(0.7722)
$\sigma = 2.25\mu$	1.5413	(1.0879)	0.3849	(0.2179)	0.7402	(0.5000)	1.5119	(1.1878)	0.3787	(0.2552)	0.6044	(0.7032)
$\sigma = 3.00\mu$	1.5413	(1.0664)	0.3860	(0.2139)	0.7173	(0.5120)	1.5613	(1.1962)	0.3917	(0.2577)	0.5535	(0.6832)
$\sigma = \sigma^\star$	1.2080	(1.0896)	0.3092	(0.2450)	0.6452	(0.6411)	1.1282	(1.1090)	0.2875	(0.2513)	0.6121	(0.6938)
Beta(12/21,3)	ϕ_0		ϕ_1		ϕ_2		ϕ_0		ϕ_1		ϕ_2	
$\sigma = 0.00\mu$	1.5893	(1.0526)	0.4078	(0.2219)	0.6943	(0.5992)	1.4960	(1.2336)	0.3722	(0.2633)	0.5503	(0.6413)
$\sigma = 0.10\mu$	1.5624	(1.0708)	0.3697	(0.2287)	0.7247	(0.6047)	1.5079	(1.2527)	0.3742	(0.2648)	0.5435	(0.6377)
$\sigma = 0.25\mu$	1.5566	(1.0711)	0.3950	(0.2282)	0.7287	(0.6001)	1.4941	(1.2411)	0.3697	(0.2624)	0.5590	(0.6350)
$\sigma = 0.50\mu$	1.5374	(1.0755)	0.3889	(0.2287)	0.7500	(0.5997)	1.4289	(1.2412)	0.3488	(0.2497)	0.6275	(0.6347)
$\sigma = 1.00\mu$	1.5624	(1.1009)	0.3931	(0.2294)	0.7280	(0.5557)	1.3458	(1.1067)	0.3356	(0.2353)	0.7243	(0.8222)
$\sigma = 1.50\mu$	1.5029	(1.1234)	0.3724	(0.2291)	0.7866	(0.5771)	1.3656	(1.1021)	0.3407	(0.2338)	0.7077	(0.8218)
$\sigma = 2.25\mu$	1.5413	(1.0879)	0.3849	(0.2179)	0.7432	(0.5513)	1.5119	(1.1878)	0.3787	(0.2552)	0.5584	(0.7424)
$\sigma = 3.00\mu$	1.5413	(1.0664)	0.3860	(0.2139)	0.7081	(0.5685)	1.5613	(1.1962)	0.3917	(0.2577)	0.5326	(0.7158)
Beta(20/21,5)	ϕ_0		ϕ_1		ϕ_2		ϕ_0		ϕ_1		ϕ_2	
$\sigma = 0.00\mu$	1.5893	(1.0526)	0.4078	(0.2219)	0.7118	(0.6203)	1.4960	(1.2336)	0.3722	(0.2633)	0.5646	(0.6734)
$\sigma = 0.10\mu$	1.5624	(1.0708)	0.3697	(0.2287)	0.7401	(0.6245)	1.5079	(1.2527)	0.3742	(0.2648)	0.5555	(0.6640)
$\sigma = 0.25\mu$	1.5566	(1.0711)	0.3950	(0.2282)	0.7442	(0.6205)	1.4941	(1.2411)	0.3697	(0.2624)	0.5723	(0.6637)
$\sigma = 0.50\mu$	1.5374	(1.0755)	0.3889	(0.2287)	0.7653	(0.6202)	1.4289	(1.2412)	0.3488	(0.2497)	0.6427	(0.6648)
$\sigma = 1.00\mu$	1.5624	(1.1009)	0.3931	(0.2294)	0.7424	(0.5754)	1.3458	(1.1067)	0.3356	(0.2353)	0.7379	(0.8479)
$\sigma = 1.50\mu$	1.5029	(1.1234)	0.3724	(0.2291)	0.8023	(0.5908)	1.3656	(1.1021)	0.3407	(0.2338)	0.7154	(0.8443)
$\sigma = 2.25\mu$	1.5413	(1.0879)	0.3849	(0.2179)	0.7598	(0.5734)	1.5119	(1.1878)	0.3787	(0.2552)	0.5726	(0.7615)
$\sigma = 3.00\mu$	1.5413	(1.0664)	0.3860	(0.2139)	0.7227	(0.5932)	1.5613	(1.1962)	0.3917	(0.2577)	0.5586	(0.7315)

Mean and standard deviation of the endogenous variables under alternative hypotheses regarding the distribution of usage and the uncertainty of future usage.