

The Doubtful Profitability of Foggy Pricing*

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Abstract

Firms engage in *foggy pricing* when they design tariff options in order to profit from consumer mistakes. This paper analyzes whether the transition from monopoly to competition in the early U.S. cellular telephone industry facilitated the use of deceptive strategies. Results indicate that competition does not appear to foster the use of deceptive strategies in general. The use of foggy pricing appears to be profitable only when consumers are very bad at predicting their future usage. Entrants always offer less foggy tariffs than incumbent firms, a result that questions that competition *per se* leads to a more frequent use of deceptive strategies. 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. There is some evidence that that a year after entry of the second firm, nonlinear tariffs offered by competing firms become *less powerful* as predicted by theoretical models of nonlinear pricing competition.

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

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“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

People commonly complain about having to make choices among “too many” options. Deliberation costs are not to be ignored as they are at the basis of this generalized state of public opinion. These psychological costs have also opened the door to important business opportunities. Not only firms may profit from misleading consumers, but also providing detailed and accurate information has become a profitable business. Thus, internet search engines have facilitated the systematic comparison of prices across stores as well as among numerous nonlinear tariff options of many services and public utilities.¹

In addition to costs associated to this complex decision process, committing to a particular contract option ahead of the consumption decision opens the possibility of mistakes that may result in substantial excess payments. The popular list of complaints includes choosing among retirement plans, health care providers and programs, loans and mortgages, options for home, car, and life insurance among others. This open ended list also includes more mundane decisions such as tariff options for utilities or cable, as well as the topic of this paper: dealing with the choice among multiple tariff plans when subscribing to cellular telephone service.

In the present work, rather than dealing with consumer behavior, I will exclusively focus on the supply side of the problem, which has, so far, attracted almost no attention at all. This paper studies *foggy pricing*, which is the practice of offering dominated tariff plans, within the menu of options offered to consumers. The purpose of foggy pricing is to extract additional surplus from gullible customers.² However, there is far more speculation and anecdotal evidence in the literature than systematic analysis of any data describing the behavior of firms in different competitive environments. This paper aims at remedying this state of affairs.

¹ At *lowermybills.com* consumers can compare the monthly dollar cost of the service that they intend to use if they subscribe to any of the companies that offer it in a particular local market. Ellison and Ellison (2004) 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 The strategic value of hidden terms and the ambiguity of the features of the tariff options that consumers face is an argument much popularized by Brandenburger and Nalebuff (1996, §7) and recently revisited by Liebman and Zeckhauser (2004) in the context of tariff design when customers have limited understanding of the tariff. “Confusion is the name of the game” is an illustrative analysis of the use of deceptive pricing in the wireless industry published by the Canadian Broadcasting Company on November 19th, 2007.

The use of deceptive strategies is a topic of considerable current interest from a public policy perspective. In the opening quote, Theresa Gattung, the former CEO of Telecom New Zealand acknowledged the use of foggy tactics by telecommunications companies. Those comments led to a government investigation, further regulation of the industry practices, and eventually her dismissal a year later. Interestingly, critics overlooked what she also said few sentences later:

“But at some level, whether they consciously articulate it or not, customers know that’s what the game has been. They know we’re not being straight up.”

So if consumers are aware of these tactics, the question is then whether their behavior will stop the use of deception in a competitive environment. Unless the market corrects the use of deceptive tactics automatically, policy makers may feel compelled to intervene in order to avoid their use as long as a generalized perception that consumers make systematic mistakes when choosing among contract options prevails.³ The belief that firms may take advantage of consumers through option proliferation and the view of consumers as naïve decision makers appears to inform the recent proposal to create a “Consumer Financial Protection Agency” with wide ranging powers. In sponsoring the new agency, President Obama declared:

“If suddenly you can, as a 20-year-old college student sign up for five different credit cards, if you find yourself able on a \$30,000 a year income to buy a \$400,000 house with no money down, then you are much more gullible to the inducements that are out there than a generation ago.”

But he also added:

“I think there would be a danger in going too far if, for example, we were restricting the ability of consumers to borrow.”

Indeed, while numerous tariff options may allow firms to take better advantage of any discerning handicaps that consumers may suffer from, having numerous choices should however not be questioned *per se* as consumers could potentially benefit from a wider selection of subscription choices. These conflicting views lead to some important questions: Why should regulatory bodies

³ In addition, see the *Leader* and *Britain* sections of *The Economist*, April 10th 2004. This suspicion has long attracted the attention the *UK Office of Fair Trading*, who investigated the benefits of limiting the number of tariff options that firms may offer to their customers. For instance, see the UK Office of Fair Trading report No. 194 on “Consumer Detriment under Conditions of Imperfect Information,” No. 168 regarding the health insurance industry, No. 255 on financial services, or the 2003 British Academy Keynes Lecture on “Economics for Consumer Policy” by the Chairman, John Vickers. There are similar ongoing investigations by the regulatory authorities of India, Perú, and other countries.

aim at restricting the choices of consumers? Should individuals simply not be given a chance to learn which companies take advantage of their mistakes in an unfair manner? Why will the market not be able to self-correct the existing strategies of deception? The present work addresses this latter empirical question and studies how foggy pricing varies with competition. If competition alone induces abandoning deceptive strategies, then favoring the entry of firms and ensuring that they do not collude will eventually eliminate the foggy pricing of tariffs. In addition, such a policy will bring the market equilibrium closer to the efficient competitive solution.

Economists have not said much about the worthiness of using deceptive strategies. Gabaix and Laibson (2006) recently showed that tactics that conceal information from consumers can only be profitable if these consumers are myopic.⁴ Moreover, from a purely empirical perspective, there is no clear indication of whether more competitive regimes would favor the use of deceptive strategies rather than inducing their disappearance. Brandenburger and Nalebuff (1996, §7) claim that firms may use foggy strategies to hide information and conform the perceptions of both their customers and competitors. These authors explicitly mention the complexity of telephone tariffs as one of the examples in which firms could use these tactics to profit from consumers who do not choose the least expensive tariff option for their telephone usage. Hence, complexity is a defining feature of the foggy pricing strategy because it makes it more difficult for consumers to compare the cost of the service across different providers.

An obvious criticism to the idea that foggy pricing is profitable is that it conforms, at best, a short run strategy. Miravete (2003) shows that telephone customers switch tariff options in an explicit attempt to reduce their monthly bills while responding to rather limited potential gains. Similarly, Economides, Seim, and Viard (2006, §4.2) notice that after the entry of new firms in the local telephone market, most switching customers realize gains that amounts to an overall increase in welfare of almost 5%. If we believe, as all this evidence appears to indicate, that consumers will eventually learn how to minimize their expenses for their usage profile, then competition may end up “lifting the fog” when other firms introduce attractive, simple, and less expensive tariff options. Indeed, this is the main finding documented in the present paper.

The empirical analysis of this paper attempts to elucidate whether a more competitive market favors the use of foggy pricing. The data set used in this paper is particularly suited to answer this question. It consists of all menus of tariff options offered by the telephone carriers of about one hundred cities in the early U.S. cellular industry between 1984 and 1992. While tariffs of that era are relatively simple by today’s standards, internet search engines were not available and

⁴ Garrod (2007) argues that naïve customers are needed to sustain the use of deceptive strategies. Ellison (2005) reviews this literature.

switching between carriers was quite expensive. Thus, if the entry of a second firm had any effect on the foginess of the tariff, we should be confident that it was due to competition alone, and not to variations in search or switching costs. The early U.S. cellular telephone industry is also an almost perfect case study because, due to an unintended failure in the process of awarding licenses, many markets operated under a monopoly regime during a significant period of time. Eventually, entry always occurred but it depended on independent judicial decisions made market by market, and thus the transition to competition can be considered exogenous.

A key issue that determines the scope of the present empirical analysis is the characterization of the foginess of a tariff. Certainly focusing only on the abundance of tariff options to choose from is not satisfactory enough and does not capture the essence of what a deceptive pricing strategy is. How can we then determine whether competition induces more or less foginess among the menus of tariff options offered to consumers? The definition of *foggy strategy* in general normally involves the fine print of contracts and generally, an unspecified measure of complexity of nonlinear functions. For the purpose of the present study a practical measure is needed, and the nature of the application allows to set a precise definition. Thus, *a particular tariff option is said to be foggy when another option or a combination of other tariff options offered by the same firm is always less expensive regardless of the usage profile of any customer*. Alternatively, it could also be said that this foggy option is dominated by another or a combination of other tariff options offered by the same firm. In the framework of the present application, this definition is accurate and comprehensive given the simplicity of cellular telephone contracts in the early U.S. cellular telephone industry.

Tariff foginess is a feature referred to the whole set of tariff options rather than just one single tariff option. I employ the ratio of dominated to non-dominated tariff options to characterize the foginess of a menu of tariffs. I also use a measure of “complexity” of non-dominated options to characterize the power of the pricing mechanism offered by firms during the monopoly and duopoly phases of the market in order to test whether competition reduces the ability of firms to extract informational rents from consumers who now enjoy better outside options than simply not participating in the market. Thus nonlinear tariffs should become flatter with competition.⁵

Results indicate that competition does not appear to foster the use of deceptive strategies in general as not all firms behave in the same manner. Entrants use *foggy* tactics far less frequently while incumbents do not increase their use relative to the monopoly phase of each market. These 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

⁵ Rochet and Stole (2002) argue that under certain circumstances, tariffs offered by competing duopolists may simplify up to the point where they consist of a couple of simple two-part tariffs.

telephone usage. The use of dynamic treatment effects reveals that most of the effect of competition on pricing is immediate with little 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 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 of Armstrong and Vickers (2001) and Rochet and Stole (2002).

The paper is organized as follows. Section 2 discusses the different measures of fogginess used in the paper. Section 3 describes the data. Section 4 studies the behavior of the suggested measures of fogginess using a difference-in-differences (*DID*) approach. This section evaluates the average treatment effect of entry of the second firm as well as dynamic treatment effects associated to the entry of the second firm in order to sort out short and long run effects of entry on foggy pricing. Section 5 addresses whether the reported results are robust to the existence of consumers' uncertainty regarding future cellular telephone usage when they sign up for a particular tariff option as well as to whether cellular phone usage patterns are more or less dispersed. Section 6 concludes.

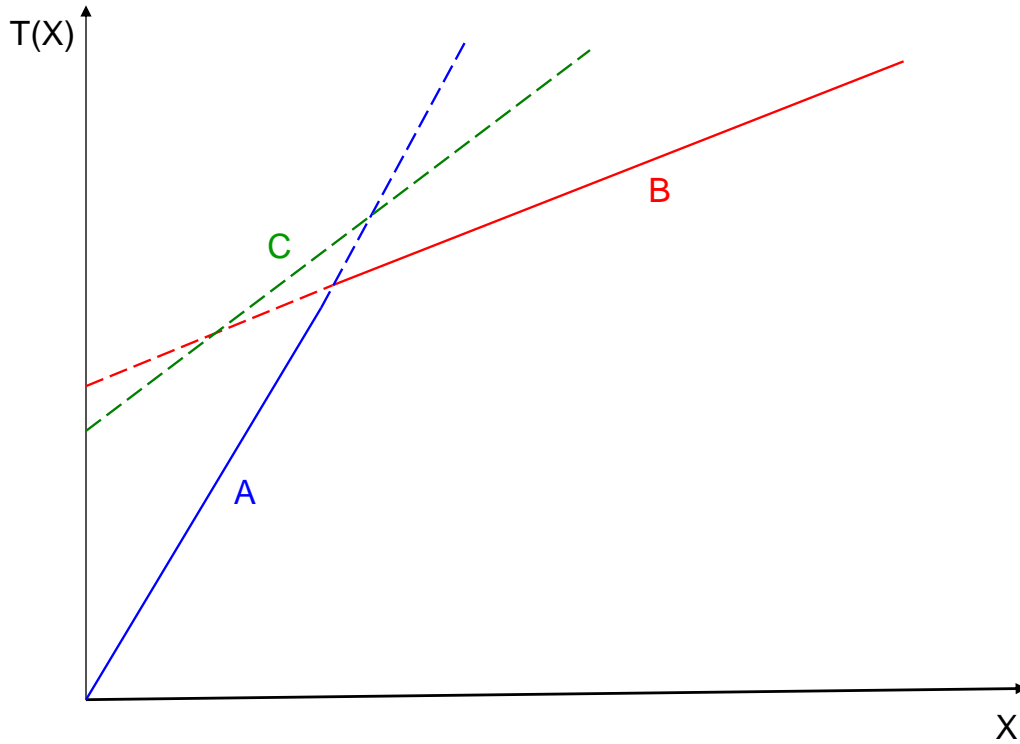
2 Defining Tariff Fogginess

An increase in the number of tariff options available to consumers may be interpreted in many ways other than throwing additional options at consumers with the hope that they make profitable mistakes when signing up for a particular tariff plan. Therefore, more precise definitions of fogginess are needed in order to conduct a meaningful empirical analysis.

An appealing and intuitive definition of foggy pricing could be the following: a foggy tariff option is totally dominated by another option or a combination of other tariff options for any usage profile possible. If consumers subscribe to a foggy tariff option, they could always reduce their expenses afterwards by switching to a different tariff plan. This situation is depicted in Figure 1. Option C is foggy because any consumer will always pay less for any usage service by subscribing to option A if she uses the telephone sparsely or to option B if she is an intensive cellular customer.⁶ The tariff of Figure 1 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 foggy tariff is robust to the existence of unobserved heterogeneity of consumers regarding their usage intensity. Tariff A targets low usage consumers while Tariff B aims to high usage consumers when attempting

⁶ 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.

Figure 1: Fogginess: Dominated Tariff Option



to maximize profits by means of price discrimination. Tariff C however, only attempts to profits from consumers' mistakes, and it is dominated no matter what distribution of usage prevails.

The available data do not contain just a representative average price of consumption for every nonlinear tariff offered but rather the complete tariff information necessary to compute the monthly bill for any profile of consumer usage. Contrary to this richness of information regarding tariff offering, data do not contain any individual subscription or consumption information. Thus, in order to determine whether an option is dominated or not, I evaluate 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.⁷ A particular option is foggy if it is never the least expensive one for at least one of approximately 500,000 potential usage patterns. Thus, a simple measure of fogginess is the total number of tariff options offered by each firm:⁸

$$\phi_0 = \text{Number of Newly Dominated Options.} \tag{1}$$

⁷ 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 1994.

⁸ The qualification of "newly dominated" is discussed below.

Thus, once we have determined whether a particular tariff is foggy, we can characterize the fogginess of a menu tariff plans as the ratio of dominated to non-dominated tariff options:

$$\phi_1 = \ln \left(\frac{\text{Number of Newly Dominated Options}}{\text{Number of Non-Dominated Options}} + 0.1 \right). \quad (2)$$

It is worth pointing out some issues related to this definition of tariff fogginess. First, 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, respectively. It is however irrelevant whether such profiles are common or alternatively, rarely found in any representative sample for this industry. What matters is that this tariff option is not always dominated by a combination of the other options. Second, this measure of fogginess increases with the proportion of dominated options relative to the non-dominated options. And third, the definition of fogginess accounts for the phasing-out of tariff options that, while being currently dominated, were non-dominated when offered in the past. Tariffs that are being phased out are not considered in the empirical analysis. This is why the numerator of this fogginess index only includes dominated tariffs that were not offered before. This is the sense in which tariff options considered are “newly dominated.” Evidently, these options being phased-out are also excluded from the denominator since they are currently dominated. Phasing-out may be used as a way to discriminate the current customer base from new subscribers if current customers were locked in into some long term contract or if they were inattentive.⁹ However, it is hardly credible that many new customers signed up for these old options when new tariff options often were simple downward parallel shifts of the old ones resulting from a reduction of the monthly fixed fee while keeping the marginal charges intact.

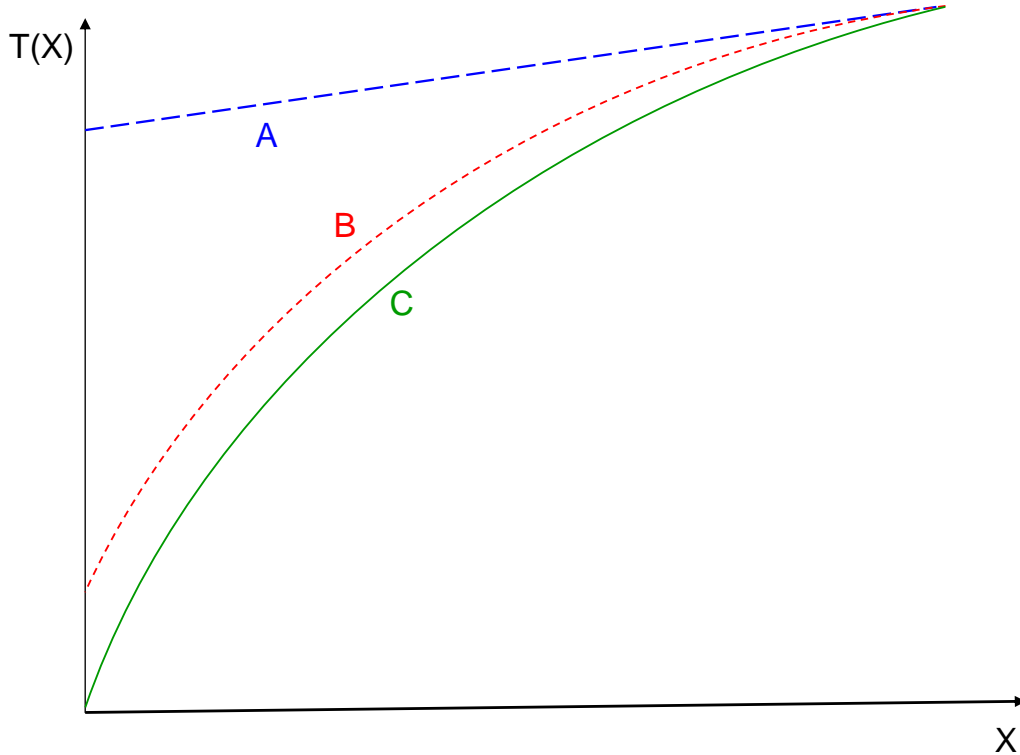
2.1 Tariff Complexity

Other than trying to take advantage of consumers, firms design nonlinear tariffs in order to extract informational rents from a base of heterogeneous customers, expand total sales, and increase efficiency by pricing larger customers closer to marginal cost. Thus, for not-deceiving sellers, the complexity of the tariff comes determined by the features of the distribution of consumer tastes.

Oi (1971) observes that if all consumers are alike a simple two-part tariff such as “Schedule A” of Figure 2 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. If consumers are heterogeneous, different unit prices need to be offered to each

⁹ Long term contracts aimed at restricting consumers from switching cellular carriers, not tariff plans.

Figure 2: Asymmetry of Information and Curvature of Nonlinear Tariffs

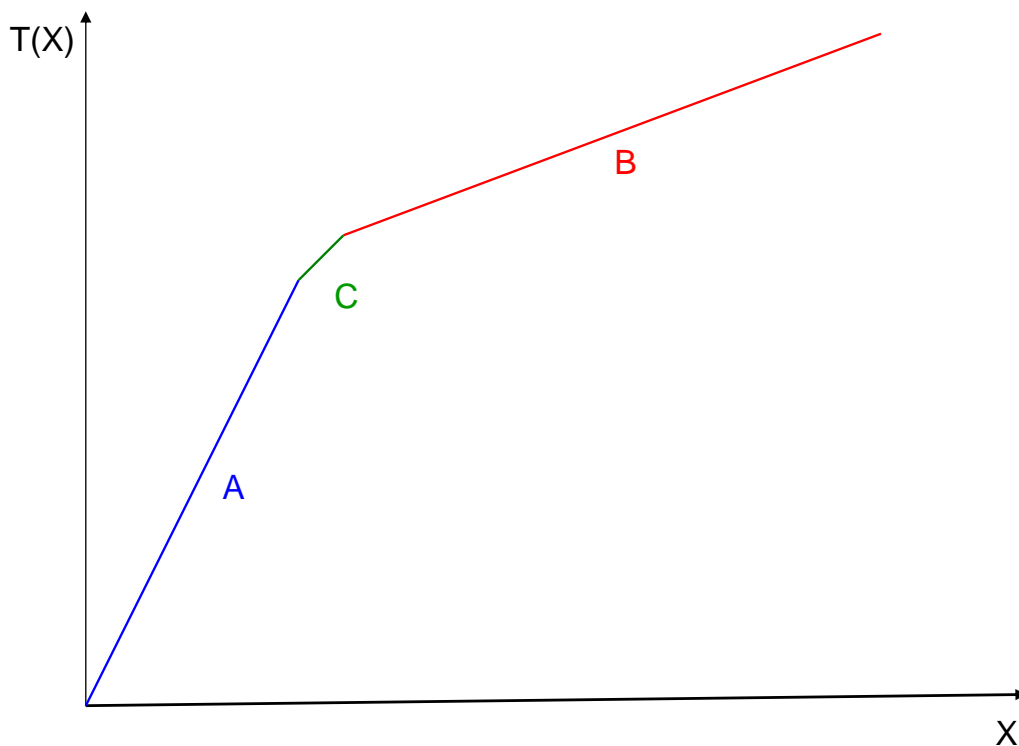


consumer type in order to extract as much surplus as possible while avoiding arbitrage. The larger the proportion of high valuation customers is, the higher are the markups that firms need to charge for low usage customers in order for the tariff to qualify as an incentive compatible contract that avoids high valuation customers mimicking the behavior of low valuation ones, *i.e.*, tariffs need to be *more powerful*. Thus, “Schedule B” is the optimal tariff when some high valuation consumers are present and “Schedule C” is optimal when the population includes many more high than low valuation customers.¹⁰

Figure 3 is a more accurate representation of the environment of the present application. Firms do not offer fully nonlinear tariffs but rather a menu of few two-part tariffs. All options represented in Figure 3 are non-dominated and define the lower envelope of the tariff offered by a particular carrier. The fact that tariff option C is the least expensive option for a 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, a monopolist could find profitable to offer a tariff option to these group of consumers without any intent of

¹⁰ 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. All tariff schedules in Figure 2 are tangent at the maximum consumption level where the marginal tariff equals the marginal cost of production.

Figure 3: Fogginess of Tariff Lower Envelope



taking advantage of their uncertainty regarding future telephone usage. Furthermore, efficiency also increases as heterogeneous consumers are offered pricing options tailored to their usage profile. Under competition though, the existence of an outside option with higher value than simply not participating reduces the ability of competing firms to extract as much consumer surplus from each individual. Thus, incentive compatibility constraints need to be relaxed and in equilibrium, possibly only one or at most two tariff options will survive, making the overall tariff lower envelope much flatter. In the limit, competition will make optimal for firms to offer only a single two-part tariff, *e.g.*, Armstrong and Vickers (2001) and Rochet and Stole (2002).

Therefore, the index of complexity (or power index) of non-dominated options needs to accommodate potential asymmetries regarding the share of usage patterns for which they are the least expensive option. To capture the effect of asymmetric menus of tariffs, I define the complexity index of a non-dominated set of tariff options as:

$$\phi_2 = \ln [\theta + 0.1] = \ln [(n \cdot HHI - 1) + 0.1] . \quad (3)$$

where n is the number of non-dominated tariff options offered and HHI is the Herfindahl-Hirschman index of concentration defined over the share of usage patterns for which each plan is the least expensive one. Considering only “balanced” tariff schedules in which each plan is the least expensive

for the same $1/n$ share of usage patterns, $\theta = 0$ 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)— the proposed index of fogginess also increases with a less balanced menu of tariffs, *i.e.*, more complex ones. Thus, in addition to foggy measures ϕ_0 and ϕ_1 , Section 4 also analyzes how competition affects the above transformation of the Herfindahl-analog measure of complexity of the lower envelope of a menu of tariff options.¹¹

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

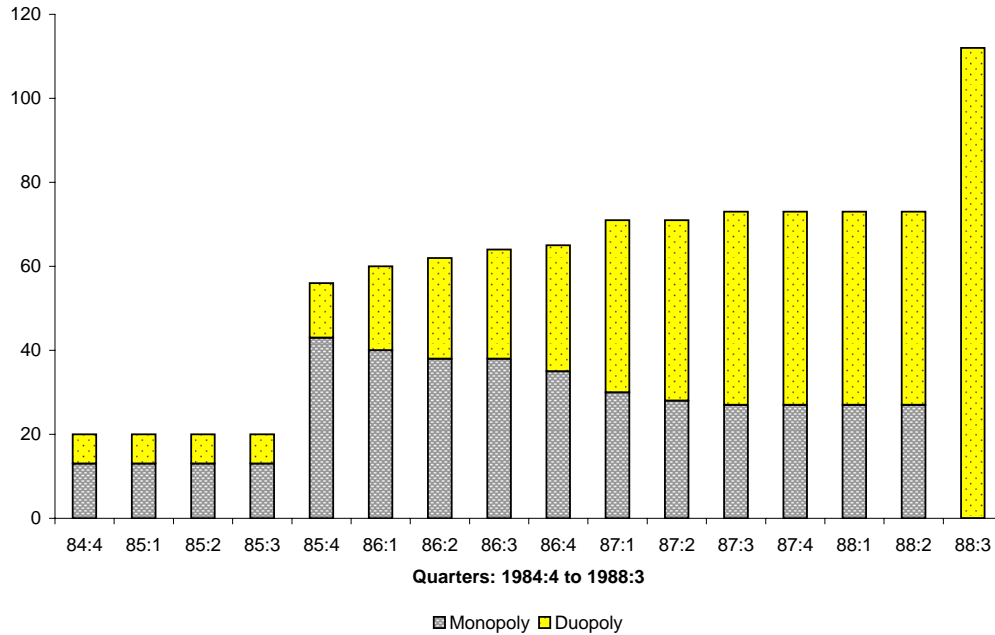
3 Pricing in the Early U.S. Cellular Industry

This paper studies the pricing strategies of numerous cellular telephone carriers in the early U.S. cellular telephone industry. The data set is unique in the sense that it includes a fairly complete description of the nonlinear tariff options offered by each firm over almost a decade. Most importantly, due to the institutional developments surrounding the awarding of licenses, data allow me to distinguish between monopoly and duopoly regimes, the transition from the former to the latter depending on an exogenous judicial decision in each market. In particular the administrative decision to award the second license to one out of hundred of applicants was customarily contested in court. Each license was decided independently of each other in a process that took several years. As the licenses were finally awarded, entrant firms had six month to be fully operative, something that was facilitated by the *FCC* requirement that the incumbent had to share its installed base of antennae with the entrant in this early stage of the market in order to promote competition.¹² Figure 4 shows the timing of the transition from monopoly to duopoly between 1984 and 1988.

¹¹ It could be argued that fogginess measures ϕ_0 and ϕ_1 may 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. Thus, ϕ_2 could serve as an alternative measure of fogginess of the lower envelope of the tariff. However, it is always possible to find a distribution of consumers' intensity of preferences that rationalizes any particular menu of options as non-foggy. Thus, I will interpret ϕ_2 only as a measure of tariff complexity.

¹² See Vogelsang and Mitchell (1997, p.207).

Figure 4: Transition to Competition



The time variation of this transition is sufficiently spread and thus, this data set proves particularly useful to analyzing the effect of competition on the use of foggy pricing.¹³

Tariffs in the early U.S. cellular industry were quite simple. A tariff option was normally a three-part tariff consisting of an allowance of “free” minutes per month, a fixed monthly fee, and a fixed rate per minute. Tariff options normally distinguish 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 completely and accurately. Other value added 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.¹⁴

The richness of the tariff information contained in the data allows me to evaluate whether a particular tariff option is dominated by one or a combination of some other available tariff options. Furthermore, it is possible to trace the history of every tariff option offered and determine whether a currently dominated option is simply the result of phasing-out previously effective options, and

¹³ For an institutional and historical account of the poorly designed awarding process of licenses in the early U.S. cellular telephone industry see Hausman (2002), Parker and Röller (1997), or Murray (2002).

¹⁴ 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, they do not influence whether a particular tariff option is more or less likely to be characterized as foggy.

Table 1: Tariffs Offered in Cleveland in 1992

<i>Incumbent: GTE Mobilnet</i>					
Plan Name	Allowance	Monthly Fee	Peak Rate	Off-Peak Rate	Usage Share
Convenience	20	24.95	0.65	0.10	96.40
Business	20	24.95	0.48	0.48	0.00
Basic Value	75	49.95	0.39	0.20	0.88
Business Saver	220	99.95	0.36	0.20	2.73
Business Advantage	400	149.95	0.28	0.28	0.06
<i>Entrant: Cellular One of Cleveland (McCaw)</i>					
Plan Name	Allowance	Monthly Fee	Peak Rate	Off-Peak Rate	Usage Share
Advantage	20	24.95	0.60	0.20	57.72
Advantage Plus	20	29.95	0.60	0.20	0.00
Basic	0	34.95	0.35	0.20	21.00
Communication II	90	55.95	0.35	0.20	7.60
Communication III	180	84.95	0.34	0.19	13.77

The allowance is measured in minutes per month. All tariff related variables are measured in dollars. The column “Usage Share” indicates the percentage of usage profiles for which each tariff plan is the least expensive option. The allocation of GTE’s “Convenience” plan includes peak minutes only and its “Business” plan does not include a \$4.95 charge for phone rental.

in such case exclude them from the analysis. Table 1 describes the features of the tariff options offered by the two competing firms in Cleveland in 1992. In addition to the features of the tariffs, the column “Usage Share” indicates the percentage of usage profiles of peak plus off-peak minutes adding up to a maximum of 1000 minutes for which each tariff is the least expensive one. The values of this last column are the basis of the empirical analysis of the rest of the paper. Those tariff plans with a zero share are foggy options according to the first definition. As Table 1 shows, both carriers offer five tariff options but while the incumbent only offers one foggy plan (“Business”), the entrant offers two foggy plans out of five options (“Advantage Plus” and “Communication II”).

Since individual tariff choice and usage data are not available, these shares are computed assuming that usage is distributed according to the beta distribution $\beta(4/21, 1)$ with mean monthly usage of 160 minutes and assuming that consumers are not uncertain about their future usage at the time of choosing tariffs. In Section 5 I repeat the analysis for different distributions of usage and degrees of uncertainty regarding future consumption. Furthermore, the time band of the allowance was unspecified most of the time. Thus, I split it between peak and off-peak consumption proportionally to each simulated usage profile.

Table 1 illustrates the idea of fogginess and phasing-out of old tariff plans that I exploit in the empirical analysis. If consumers of Cellular One were certain about their future usage, the “Advantage” plan completely dominates the “Advantage Plus” plan for any usage pattern as the

latter is simply five dollars more expensive every month than the former. How is it possible that anybody sign up for the always more expensive “Advantage Plus” plan? One possibility is that this is an old effective tariff that is being phased out. If “Advantage Plus” is a non-dominated option offered by Cellular One in Cleveland for earlier periods I conclude that this tariff option is being phased out and it does not enter into the computation of the fogginess measures. If “Advantage Plus” (and tariffs alike) were not offered in the past, then they are used to compute the first measure of fogginess.

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. Each market is defined around a standard metropolitan statistical area, (*SMSAs*) and only two cellular carriers are allowed to compete against each other. Data include the largest one hundred metropolitan areas in the U.S. These markets operated independently of each other and entry of the second carrier needs to happen within six months of separate and independent judicial decisions. The identity of the entrant and the timing of entry of the second firm can thus be considered largely exogenous. This information is complemented with data collected by Marciano (2000) for year 1992, when all markets had already been served by two competing firms for quite some time.¹⁵ Including the 1992 data adds observations from more mature markets and allows me to identify whether pricing strategies are qualitatively different when one firm grows at the expense of the competing carrier rather than expanding the customer base.

Table 2 shows that in monopolistic markets, one third of the firms only offered a single tariff option, and almost 40% between 2 and 3 options only. The transition from monopoly to duopoly clearly increased the alternatives available for consumers to choose from. Two thirds of the firms offered 3 or 4 options in the early duopoly phase while in 1992 half of all firms offered 5 options. The second half of Table 2 reports the frequency distribution of those tariff options that are non-dominated. Competition adds on average between 1 and 1.5 tariff options per firm in the short and long run, respectively. Similarly, the average number of effective plans per firm increases less dramatically in the short run —only about 0.3 plans per firm— but significantly more in the long run, *i.e.*, 1.2. Thus, it appears that on aggregate, competition triggers the use of foggy pricing in the short run but as market becomes more mature firms use deceptive tactics less intensively. The following section evaluates whether these unconditional results still hold once we account for firm, market, and time specific effects.

¹⁵ 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.

Table 2: Frequency Distributions of the Number of Tariff Options (1984-1988)

TOTAL Opt.	<i>Monopoly</i>		<i>Duopoly</i>			
	<i>Incumbent</i>		<i>Incumbent</i>		<i>Entrant</i>	
	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 Opt.	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	56	0.1107
4	14	0.0340	17	0.0326	36	0.0711
5			2	0.0038	7	0.0138
Mean/(Var.)	1.4879	(0.4986)	1.5624	(1.1466)	1.5079	(1.5692)

Absolute and relative frequency distribution of the number of actual and non-dominated tariff options offered by each active firm in each market-quarter combination.

4 Foggy Pricing: From Monopoly to Competition

An increase in the number of options available to consumers could be interpreted in different ways. Seim and Viard (2005) argue that competition leads to an increase of variety for consumers. Alternatively, we could think that competition induces firms to become more sophisticated in their attempt to extract informational rents from consumers. Thus, firms increase their expected profits by better screening among different consumer types. The foggy tactics explanation would conclude that this increase in the number of options is 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 increases the fogginess of the tariffs.

Table 3 shows that the number of tariff foggy options vary 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 the 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 only represent 0.97% in monopoly while this situation accounts for 8.06% of the pricing for incumbent and 2.77% for the entrant. Therefore,

Table 3: 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	1.98	7.11	1.38

Percentage of total cases for each tariff combination. Rows denote the number of total options while columns are the number of non-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.

there are movements in the opposite direction, and thus the effect of competition on the fogginess of tariffs offered is ambiguous. To evaluate the effect of entry on foggy pricing, I conduct a *DID* econometric analysis in which I control for market and time fixed effects separately for incumbent and entrant firms. The goal of this 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 DUOPOLY.¹⁶

Table 4 reports the descriptive statistics of these variables as well as those related to the tariffs. They include the number of tariff plans (PLANS), how many of them are actually non-dominated (EFFPLANS), the ratio of newly dominated to total non-dominated tariffs (SHARE-FOGGY), and the measure of complexity of the menu of non-dominated options (COMPLEXITY) as defined by equation (3). Table 4 also includes AP_{peak} and $AP_{\text{off-peak}}$, two “Arrow-Prat analogue” measures of the curvature of the peak and off-peak dimension of tariffs. Variable AP_{peak} is the equivalent

¹⁶ All other firm and market demographics available are time invariant and thus they are not identified in a *DID* framework.

Table 4: Descriptive Statistics (1984-1988)

Variables	<i>Monopoly</i>		<i>Duopoly</i>			
	<i>Incumbent</i>		<i>Incumbent</i>		<i>Entrant</i>	
	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
AP _{off-peak}	0.5845	3.2887	-11.2009	99.4176	1.0395	45.7270
AVGjLEADj	0.0000	0.0000	2.3455	2.2544	2.3702	2.2583
AVGjSHFj	0.0000	0.0000	0.2595	0.2134	0.2622	0.2135
AVGjHHFj	0.0000	0.0000	0.4204	0.3658	0.4215	0.3628
Observations	412		521		506	

All variables are defined in the text.

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 AP_{off-peak} is defined similarly but using the off-peak component of the tariff only.¹⁷ Lastly, AVGjLEADj, AVGjSHFj, and AVGjHHFj are used as instruments for AP_{peak} and AP_{off-peak}. They refer to the average lead and measure of fogginess and tariff complexity of competitors during previous periods in other markets where the competing firm operates.

Table 5 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 and the duopoly phase only the pricing behavior of the entrant. I proceed in this way, not pooling the pricing behavior of the incumbent and the entrant during the duopoly phase, to avoid potential strategic effects. This would be the case if deception or complexity become strategic decision variables of these firms, which will turn the task of identifying the effect of competition on pricing practices into a much more involved task.

¹⁷ This approach is equivalent to the discrete Arrow-Pratt measure employed by Marciano (2000, §4.2) to account for the curvature of the tariff. Busse and Rysman (2005) used a Cobb-Douglas approximation to the lower envelope of the tariff to account for the extent of asymmetry of information.

Table 5: Fogginess – Average Treatment Effects

INCUMBENT	ϕ_0 (<i>PMLE</i>)		ϕ_1 (<i>OLS</i>)		ϕ_2 (<i>OLS</i>)	
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)
AP _{off-peak}	0.0000	(1.04)	0.0000	(0.10)	-0.0004	(3.44)
<i>DPLRI/ Adj. R</i> ²	0.5964		0.6808		0.6806	
<i>LM</i> (Joint Test)	2.9383	[0.2301]	0.2988	[0.5847]	0.0063	[0.9370]
ENTRANT	ϕ_0 (<i>PMLE</i>)		ϕ_1 (<i>OLS</i>)		ϕ_2 (<i>OLS</i>)	
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)
AP _{off-peak}	-0.0000	(0.96)	-0.0001	(0.03)	0.0003	(0.03)
<i>DPLRI/ Adj. R</i> ²	0.6401		0.6958		0.6576	
<i>LM</i> (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 between 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. The corresponding p-values are shown between brackets. Sample includes 1,004 observations for the incumbent and 989 for the entrant.

All regressions include time (quarter) and market (city) fixed effects. In general, these (non-reported) results are significant. Among the former I only report YEAR92 to document pricing differences once the market has settled. The first column reports 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 report the estimates of ordinary least square regressions to evaluate the impact of competition on deceptive pricing and tariff complexity, respectively. In computing all fogginess measures, 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 option 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 follow well differentiated strategies. Regarding tariff fogginess, incumbent firms increase the use of deceptive options in a competitive environment while entrants reduce its use by an almost identical magnitude. Thus, it is the entrant who makes pricing less foggy. Since firms follow opposite strategies, we cannot conclude that competition completely 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.

As for the complexity of the tariff lower envelope, the incumbent appears to offer more effective options to consumers while the entrant offer 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.¹⁸ 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 5.

The measures of concavity of the tariff schedule AP_{peak} and $AP_{\text{off-peak}}$ can be considered exogenous in all but one case. It is interesting to analyze the effect of AP_{peak} on the pricing behavior of the entrants results indicate that pricing by the incumbent do not respond significantly to consumers usage heterogeneity as measured by the concavity of the tariff lower envelope. If consumers were very similar the optimal nonlinear tariff will almost surely be a simple two-part tariff (as discussed in Figure 2). Thus, the Arrow-Pratt measure of degree of concavity would approach zero. In general, it is in those cases when entrant firms offer more often foggy options as seen by the significant negative estimate of AP_{peak} in the ϕ_1 equation. This result indicates that entrants make use of deceptive strategies when adding another effective tariff option to further segment the market leads to a very low increase in expected profits. This result is consistent with the argument put forward in the theoretical model of Yang and Ye (2008). On the contrary, when consumers are very diverse, it is profitable to offer them a large number of tariff options, even though some of them are only the least expensive option for a small range of telephone usage. This theoretical prediction is corroborated by the significant positive estimate of AP_{peak} in the ϕ_2 equation.¹⁹

¹⁸ It is well documented that in the 1990, 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).

¹⁹ Carlin (2008) suggests an interesting additional alternative that unfortunately cannot be tested with this data set because of the absence of individual data. Carlin (2008) shows that adding complexity to the pricing of financial products may increase profits when consumers are rational but face heterogeneous search costs. Thus, an increase in competition foster the use of complex pricing because the increase of the customer base reduces the chances that a firm encounters informed consumers.

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.²⁰ 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. $TREAT(0) = 1$ indicates the quarter where the second firm enters the industry. $TREAT(+1) = 1$ 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. $TREAT(\geq +6) = 1$ identifies the sixth quarter after the entry of the second carrier and all quarters thereafter. Thus, $TREAT(\geq +6)$ captures the long term effect of competition. Results are robust if I increase the number of quarters considered.

Table 6 repeats the analysis of Table 5 but including dynamic treatment effects instead of just the dummy variable, $DUOPOLY$, to identify the transition from monopoly to competition. The *LM* test of endogeneity cannot reject the hypothesis that AP_{peak} and $AP_{off-peak}$ are jointly exogenous and estimates of AP_{peak} , $AP_{off-peak}$, and $YEAR92$ are very close to those reported in Table 5. 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.

For the most part, incumbents offer the same number of foggy options (ϕ_0) before and after the entry of the second carrier. The only exception happens fifteen months after entry, when the number of foggy options becomes temporarily larger. 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 only six months after the entry of the second cellular carrier. Entrants, on the contrary, reduce the fogginess of tariffs immediately

²⁰ 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 6: Fogginess – Dynamic Treatment Effects

INCUMBENT	ϕ_0 (<i>PMLE</i>)		ϕ_1 (<i>OLS</i>)		ϕ_2 (<i>OLS</i>)	
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($\geq+6$)	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)
AP _{off-peak}	0.0000	(1.05)	0.0000	(0.16)	-0.0004	(3.29)
<i>DPLRI</i> / <i>Adj. R</i> ²	0.5974		0.6802		0.6833	
<i>LM</i> (Joint Test)	3.6038	[0.1650]	0.4290	[0.5125]	0.0001	[0.9918]
ENTRANT	ϕ_0 (<i>PMLE</i>)		ϕ_1 (<i>OLS</i>)		ϕ_2 (<i>OLS</i>)	
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($\geq+6$)	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)
AP _{off-peak}	-0.0000	(0.89)	-0.0001	(0.03)	0.0003	(0.03)
<i>DPLRI</i> / <i>Adj. R</i> ²	0.6419		0.6951		0.6575	
<i>LM</i> (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 between 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. The corresponding p-values are shown between brackets. Sample includes 1,004 observations for the incumbent and 989 for the entrant.

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, perhaps indicating that they get adjusted to competition. Thus, tariffs become simpler, *i.e.*, the prediction of theoretical models of nonlinear pricing competition such as Armstrong and Vickers (2001) or Rochet and Stole (2002). Nevertheless, this process takes a long period to materialize and eighteen months after the entry of the second firm, there is no conclusive evidence that tariffs become simpler across competitors.

Figure 5: Dynamic Competition Effects on ϕ_0

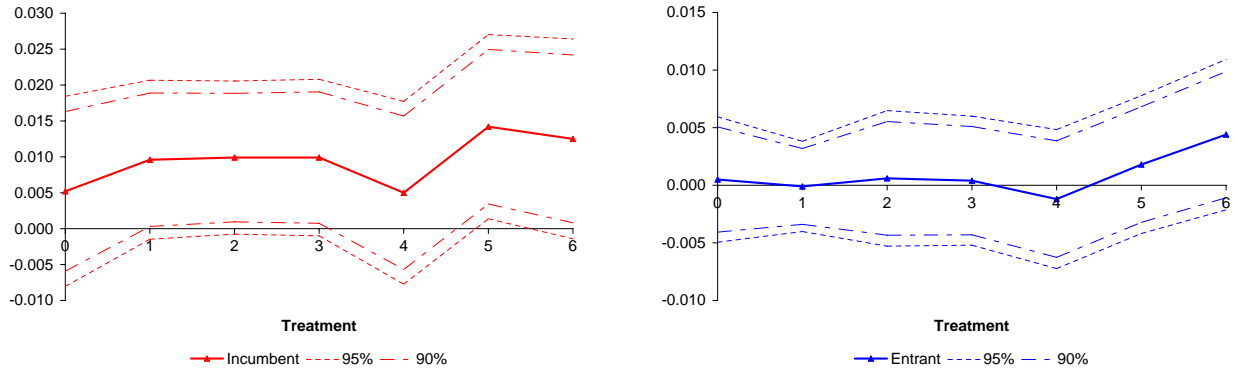


Figure 6: Dynamic Competition Effects on ϕ_1

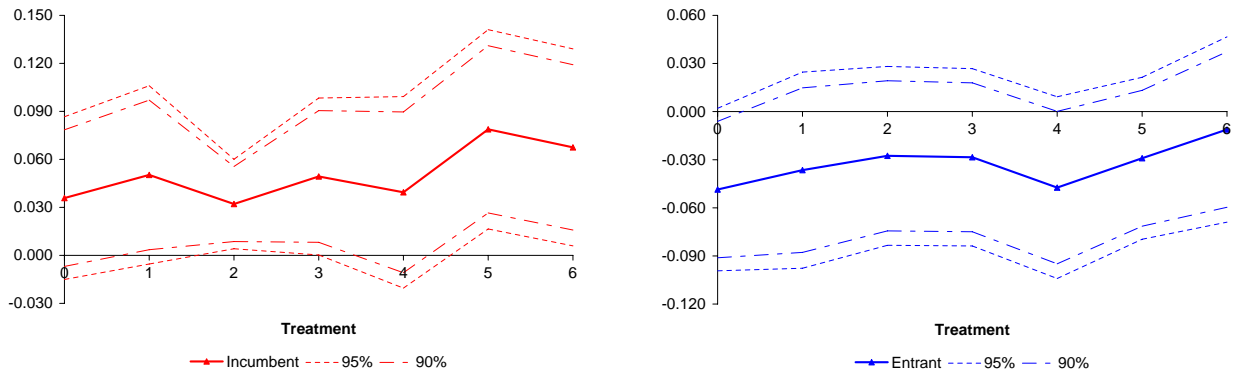


Figure 7: Dynamic Competition Effects on ϕ_2

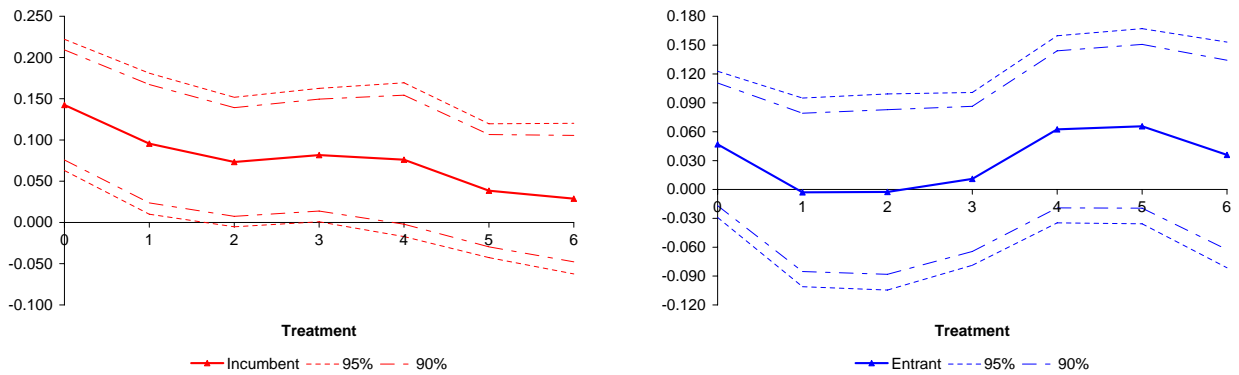


Table 7: Fogginess – Incumbent: Preemption

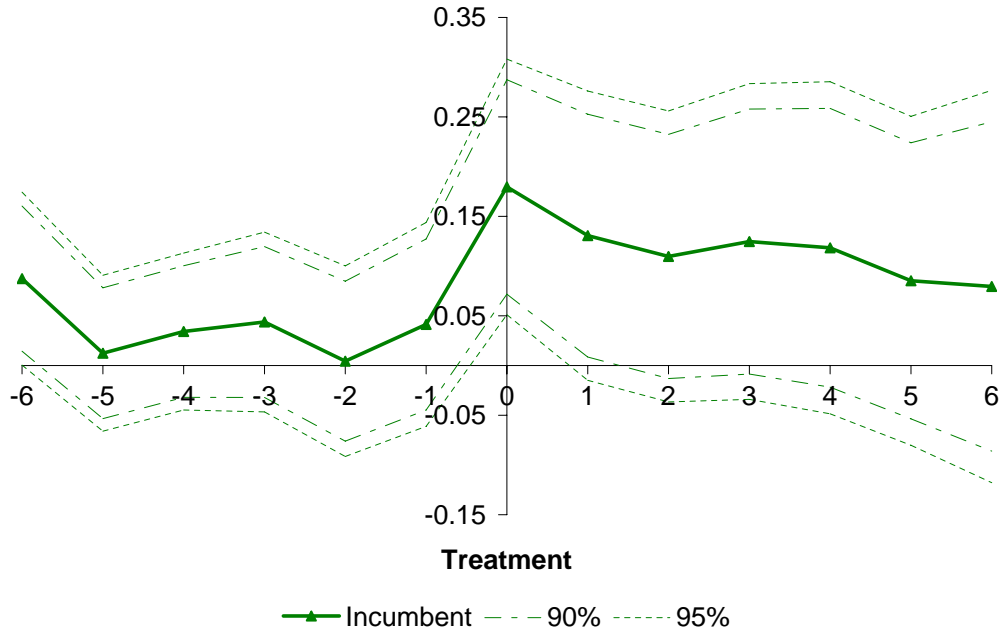
	ϕ_0 (<i>PMLE</i>)		ϕ_1 (<i>OLS</i>)		ϕ_2 (<i>OLS</i>)	
YEAR92	0.0075	(0.49)	-0.0218	(0.29)	0.1560	(1.32)
TREAT(-6)	-0.0004	(0.07)	0.0179	(0.74)	0.0874	(1.97)
TREAT(-5)	0.0066	(1.01)	0.0314	(1.14)	0.0124	(0.31)
TREAT(-4)	0.0029	(0.44)	0.0255	(0.81)	0.0342	(0.85)
TREAT(-3)	-0.0001	(0.01)	0.0062	(0.20)	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($\geq +6$)	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)
AP _{off-peak}	0.0000	(1.04)	0.0000	(0.14)	-0.0004	(3.28)
<i>DPLRI</i> / <i>Adj. R</i> ²	0.5977		0.6788		0.6830	
<i>LM</i> (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 between 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 exogeneity. The corresponding p-values are shown between brackets. Sample includes 1004 observations.

One possibility that might question the validity of most results reported so far is that the incumbent preempts 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, Table 7 now includes thirteen dummies for thirteen consecutive quarters, some of them before entry of the second firm actually happened. Figure 8 illustrates the argument.

Estimates show that incumbent firms do not vary their pricing tactics in any way, whether regarding the number of foggy options, the fogginess of the menu of options offered, or the complexity of the tariff lower envelope relative to their pricing a year and a half before entry of the second competitor. Indeed, as Figure 8 shows the only significant dynamic effect is a sudden increase in the complexity of the tariff lower envelope precisely at the time of entry of the second carrier, not before. Thus, all previous results remain valid and document a differentiated behavior of incumbent and entrant firms regarding tariff fogginess and complexity.

Figure 8: Preemptive Effects on ϕ_2



4.2 Instrumental Regressions

The curvature of tariffs, as measured by AP_{peak} and $AP_{\text{off-peak}}$, are simultaneously chosen with the menu of tariffs offered to consumers and thus, it is questionable whether the options offered responded to an optimizing behavior of firms that take the distribution of their customers' telephone usage as given (exogenous), or whether our measure of concavity is just the result of the pricing decisions of firms and independently of the distribution of consumer tastes (endogenous). In all but one case, the *LM* test of endogeneity fails to reject the null hypothesis of exogeneity of AP_{peak} and $AP_{\text{off-peak}}$ in Tables 5 and 6. Given these results I did not report the estimates after instrumenting for AP_{peak} and $AP_{\text{off-peak}}$ as they are virtually identical to those of Tables 5 and 6. I will however discuss briefly the strategy followed to select instruments among the available information. Table 8 reports the results of the corresponding instrumental regressions.

There are almost no time varying regressors left once we include time and market specific dummies in the estimated *DID* model. I thus exploit the panel data structure of the data to obtain additional instruments as suggested by Hausman, Leonard, and Zona (1994) and Hausman (1996). Let consider the incumbent carrier in a particular market. I use as instruments the features of the tariffs offered in the past by the entrant in other markets. These features are orthogonal to the foginess of the incumbent's tariff in the market under consideration as long as the reasons to engage in foggy pricing are market specific rather than nationally driven. Pricing features of the entrant in other previous markets are however informative of her pricing tactics in the market under

Table 8: Instrumental Regressions

Table 5			Table 6			Table 7		
	AP _{peak}	AP _{off-peak}	AP _{peak}	AP _{off-peak}	AP _{peak}	AP _{peak}	AP _{off-peak}	AP _{off-peak}
YEAR92	-0.0033 (0.03)	12.7393 (1.27)	0.1482 (0.59)	5.4098 (1.18)	0.1551 (0.80)	22.5585 (1.37)		
DUOPOLY	0.0814 (1.25)	1.7590 (0.32)	-0.0134 (0.08)	-4.6994 (1.71)	-0.0264 (0.33)	9.9510 (1.21)		
AVGjLEADj	0.0210 (1.01)	2.2249 (1.62)	-0.0083 (0.24)	2.4152 (1.02)	-0.0408 (0.55)	9.4008 (1.28)		
AVGjSHFj	-0.1946 (0.93)	2.6614 (0.05)	-0.3389 (0.49)	-33.1562 (0.95)	-0.0508 (0.58)	8.6012 (1.28)		
AVGjHHFj	-0.0356 (0.47)	-40.6930 (1.33)	-0.1685 (0.56)	-12.8090 (1.06)	-0.0465 (0.49)	7.5132 (1.07)		
<i>Adj. R</i> ²	0.1546	0.4909	0.3688	0.4620	-0.3636 (1.11)	5.3284 (0.76)		
<i>LM</i> (Joint Test)	2.5883 [0.2741]	2.8212 [0.2440]	0.5457 [0.7612]	3.3668 [0.1857]	-0.0616 (0.58)	4.7728 (0.59)		
YEAR92	-0.0480 (0.33)	30.1987 (2.26)	0.4672 (1.35)	6.5568 (1.18)	-0.1002 (0.76)	-0.1934 (0.02)		
TREAT(-6)	0.0224 (0.30)	-7.7382 (0.89)	-0.1945 (0.98)	-5.5946 (1.32)	0.0819 (0.66)	14.3184 (1.11)		
TREAT(-5)	0.1822 (2.14)	7.2494 (0.66)	0.0677 (0.24)	-3.9223 (1.37)	0.0803 (0.56)	13.5652 (0.90)		
TREAT(-4)	0.1988 (1.92)	6.5287 (0.50)	0.1091 (0.40)	-4.0705 (1.37)	0.1191 (0.82)	13.8442 (1.06)		
TREAT(-3)	0.2356 (2.26)	6.4513 (0.54)	0.1224 (0.48)	-4.1455 (1.37)	0.0788 (0.50)	-7.5918 (0.71)		
TREAT(-2)	0.2253 (1.99)	-15.3911 (1.21)	-0.3179 (0.94)	-4.0808 (1.09)	0.0824 (0.48)	-7.1958 (0.61)		
TREAT(-1)	0.2176 (2.05)	-15.5677 (1.24)	-0.3105 (0.89)	-4.1684 (1.17)	0.0397 (0.18)	-7.6736 (0.73)		
TREAT(0)	0.2183 (1.73)	-17.1922 (1.63)	-0.3424 (1.19)	-5.3253 (1.16)	0.0004 (0.02)	2.7399 (1.58)		
TREAT(+1)	0.0065 (0.36)	2.4976 (1.51)	-0.0061 (0.20)	3.3241 (0.98)	-0.4151 (1.52)	11.7683 (0.22)		
TREAT(+2)	-0.3707 (1.41)	10.1510 (0.20)	-0.2305 (0.29)	-33.6756 (0.97)	-0.1092 (1.17)	-41.7008 (1.34)		
TREAT(+3)	-0.1027 (1.17)	-41.9350 (1.35)	-0.1996 (0.75)	-13.1949 (1.08)	0.1627 (0.80)	0.4919 (1.21)		
TREAT(+4)	0.1520 (0.30)	0.4946 (0.89)	0.3710 (1.35)	0.4583 (1.08)	2.8048 [0.2460]	1.8950 [0.3877]		
TREAT(+5)	2.8570 [0.2400]	2.3876 [0.3031]	0.8963 [0.6388]	3.1478 [0.2072]				
TREAT(≥+6)								
AVGjLEADj								
AVGjSHFj								
AVGjHHFj								

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 2 degrees of freedom under the null hypothesis of validity of the instruments. Its p-value is shown between brackets.

consideration, and they will be correlated with the curvature of the incumbent’s tariff because in equilibrium the tariffs offered by the competing firms determines the effective distribution of consumer types that each one of them faces. The same argument applies to the entrant. Discarding current or future characteristics of the tariff of the competing firm in other markets avoids the possibility that the entrant’s current tariff influences the pricing of the competitor elsewhere in later periods.

I use the last three variables of Table 4, $AVGjLEADj$, $AVGjSHFj$, and $AVGjHHFj$ as instruments for AP_{peak} and $AP_{\text{off-peak}}$ in regressions reported in tables 5 to 7. If firm i and j compete in several markets, when analyzing the pricing of firm i these instruments denote the average lead of the incumbent carrier in those markets measured in months, the average share of foggy options, and the average degree of complexity of the tariff lower envelope, respectively; all of them referred to the tariffs offered in the past by the competing firm j in other markets. Entry of the firm or its competitor in other markets is exogenous but it may account for experience and learning consumer behavior and thus conditioning pricing in those markets. The *LM* overidentifying restriction test reported in Table 8 indicates that these variables are in general good instruments.

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 reasonable 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. In particular, I repeat the analysis assuming that cellular phone usage is distributed according to beta distributions $\beta(4\kappa/21, \kappa)$ for $\kappa = 1, 2, \dots, 5$ on the 0 to 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 with κ .

Table 9 reports the effect of the most critical variables of the analysis after recomputing fogginess measures for different values of κ . In the case of DUOPOLY the first line corresponds to the estimates of this variable in Table 5 while for the rest of variables it matches those of Table 6. Results of Table 9 confirms all results of Section 4, and in particular that incumbent and entrant

Table 9: Heterogeneity of Usage Patterns: Alternative Distributions

	INCUMBENT (Table 5)				ENTRANT (Table 6)				
	ϕ_0 (PMLE)	ϕ_1 (OLS)	ϕ_2 (OLS)	ϕ_0 (PMLE)	ϕ_1 (OLS)	ϕ_2 (OLS)	ϕ_0 (PMLE)	ϕ_1 (OLS)	ϕ_2 (OLS)
DUOPOLY									
$\beta(4/21, 1)$	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)			
YEAR92									
$\beta(4/21, 1)$	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)									
$\beta(4/21, 1)$	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)									
$\beta(4/21, 1)$	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($\geq +6$)									
$\beta(4/21, 1)$	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, heteroskedastic-consistent t-statistics are reported between parentheses while in the case of 2SLS absolute Wooldridge (1995) heteroskedastic-consistent t-statistics are reported between parentheses. DUOPOLY variable refers to the regression with a single average treatment effect while the rest are the estimates the regression including dynamic treatments.

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.²¹

The analysis of Section 4 was carried out under the implicit 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 control for heterogeneity regarding the existence of individual uncertainty with respect to future telephone usage at the time of signing up for a particular tariff option.²² Putting it differently, it is as if consumers were subscribing to a particular tariff plan simultaneously with choosing their telephone usage so that they always subscribed to the least expensive option available for such specific usage profile. Evidently consumers do not choose tariff options and telephone usage simultaneously in real life. Indeed, 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.

In the absence of individual subscription and usage data I evaluate the robustness of the results of Section 4 to the existence of heterogeneity of individual uncertainty regarding future usage by means of simulations. For the analysis of Tables 5 and 6 I first determined which tariff option was the least expensive for each potential usage profiles defined by all 501,501 combinations (i, j) where $i = 0, 1, 2, \dots, 1000$ represented the number of peak minutes a household uses during a month and $j = 0, 1, 2, \dots, 1000$ were the corresponding off-peak minutes of usage. Moreover, it was assumed that $i + j \leq 1000$ and that usage was distributed according to a beta distribution $\beta(4/21, 1)$ so that the average usage profile is 160 minutes a month, a magnitude that is representative of the monthly usage during this early market. Furthermore, this distribution also 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.

Now, 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

²¹ Notice that estimates involving either ϕ_0 or ϕ_1 are robust to the distribution of consumer preferences regarding telephone use. Whether all consumers use the telephone identically, more intensively, or just to make few emergency calls does not affect the fact that one foggy option is always more expensive than the rest. The same reasoning cannot be extended to ϕ_2 since the share of consumers that end up choosing a particular tariff option depends critically on the distribution of telephone use.

²² Tariffs offered by the competing carriers in the early U.S. cellular industry commonly included an allowance, a fixed monthly fee, and a single rate per minute. These are called three-part tariffs and they have been proven to be an optimal screening mechanism in the presence of consumer (unbiased) uncertainty by Lambrecht, Seim, and Skiera (2007). Grubb (2009) further allow consumers to be overconfident, *i.e.*, they underestimate the variance of their future consumption, in order to characterize a three-part tariffs as an optimal screening mechanism of type-varying consumers.

Table 10: Fogginess and Uncertainty: Dominated and Non-Dominated Tariff Options

DUOPOLY	INCUMBENT (Table 5)						ENTRANT (Table 6)					
	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)
$\sigma = \sigma^*$	0.0071	(1.81)	0.0426	(1.93)	0.1229	(3.47)	-0.0008	(0.16)	-0.0284	(0.00)	0.0421	(1.15)
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)
$\sigma = \sigma^*$	0.0071	(0.87)	0.0379	(0.83)	-0.0515	(0.64)	-0.0060	(0.69)	-0.0269	(0.71)	0.1386	(1.36)
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)
$\sigma = \sigma^*$	0.0074	(1.39)	0.0389	(1.30)	0.1508	(3.34)	0.0004	(0.07)	-0.0380	(1.27)	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)
$\sigma = \sigma^*$	0.0075	(1.43)	0.0434	(1.34)	0.0906	(1.92)	-0.0017	(0.28)	-0.0279	(0.94)	0.0209	(0.46)
TREAT($\geq+6$)	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)
$\sigma = \sigma^*$	0.0095	(1.58)	0.0529	(1.77)	0.0738	(1.59)	0.0115	(1.60)	0.0125	(0.40)	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 between parentheses while in the case of 2SLS absolute Wooldridge (1995) heteroskedastic-consistent t-statistics are reported between parentheses.

around (μ_i, μ_j) , truncated at zero, and such that $\mu_i + \mu_j \leq 1000$. Thus, μ_i and μ_j represent the expected number peak and off-peak number of calls, respectively, that a household makes 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.*, $\sigma_i = \lambda\mu_i$ and $\sigma_j = \lambda\mu_j$, respectively. This heteroskedastic assumption captures the documented dispersion of telephone usage for different usage levels (*e.g.*, see Miravete (2005, §4)). Therefore, for each of the 501,501 expected usage profiles defined by (μ_i, μ_j) , 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 $N[\mu_i, (\lambda\mu_i)^2]$ for peak usage and another fifty from $N[\mu_j, (\lambda\mu_j)^2]$ for off-peak usage. Accordingly, the first fogginess measure is defined on whether an option is always more expensive than the others *in expectation*, therefore treating consumption and subscription as two separate decisions. Thus, if option C is sufficiently close to the intersection of options A and B as in Figure 1, and for a disperse enough distribution of prediction errors, it is possible that option C is no longer dominated for all potential expected realizations of usage. Similarly segment C in Figure 3 may capture a larger share of expected usage profiles as it includes realizations of usage profiles in the adjacent A and B options.

Finally, to further address the possibility of heterogeneity with regard to uncertainty, Table 10 also includes the case where individuals are randomized from different $N[\mu_j, (\lambda\mu_j)^2]$ distributions. The case where $\sigma = \sigma^*$ builds a sample of size 501,501 by randomly sampling from the other eight samples with identical probability. Lastly, I also report the value of the descriptive statistics of ϕ_0 , ϕ_1 , and ϕ_2 for the incumbent and entrant firm distinguishing simultaneously by degrees heterogeneity regarding usage and uncertainty in Table 11.

Despite all these considerations Table 10 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. This is always true for the case of ϕ_0 , the number of foggy options, and ϕ_2 the measure of complexity of the tariff lower envelope, both for the incumbent and the entrant. Results become less significant for larger σ when we consider the average treatment effect of competition (*i.e.*, the static case). Incumbent firms still increase the fogginess of their tariff menus if customers are uncertain regarding their future consumption. However, that effect becomes marginally significant at 10% significance level or less when the distribution of expected usage is very spread. This is the only case where considering individuals that are heterogeneous with respect to their uncertainty, *i.e.*, $\sigma = \sigma^*$, has any tangible consequence: the average treatment effect of duopoly on ϕ_1 remains still positive and significant. Finally, as for the average treatment effect of duopoly on the deceptive pricing behavior of entrant firms, Table 10 shows that it is still negative unless the variance of the expected future usage becomes

Table 11: Fogginess and Uncertainty: Measures of Fogginess (Duopoly Phase)

		<i>INCUMBENT</i>						<i>ENTRANT</i>					
		Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
		ϕ_0	ϕ_1	ϕ_2	ϕ_0	ϕ_1	ϕ_2	ϕ_0	ϕ_1	ϕ_2	ϕ_0	ϕ_1	ϕ_2
<i>Beta(4/21,1)</i>													
$\sigma = 0.00\mu$		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)
$\sigma = \sigma^*$		1.5551	(1.0614)	0.3933	(0.2223)	0.7385	(0.5401)	1.4781	(1.2097)	0.3668	(0.2575)	0.6367	(0.6810)
<i>Beta(12/21,3)</i>													
$\sigma = 0.00\mu$		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)
<i>Beta(20/21,5)</i>													
$\sigma = 0.00\mu$		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.

very large relative to its expected value. Here again, incumbent and entrant firms show very different behavior: deception does not pay off for low levels of uncertainty, *i.e.*, when consumers are moderately accurate in their predictions. In such an scenario, incumbent firms do not increase the fogginess of their menu of tariff options relative to the pricing practices of the monopoly phase while entrant firms make their tariff offering far less deceptive. At the other end, when consumers are very uncertain about future telephone usage, incumbent firms increase the fogginess of their tariffs while the entrant offers tariffs that do not differ much from those of incumbent monopolists with respect to fogginess. In both cases, the entrant always make use of less deceptive strategies.²³

6 Concluding Remarks

To the best of my knowledge, this paper provides the first evaluation of firms' use of deceptive strategies. I make use of a rich data set with detailed information on all tariff options offered by a multitude of cellular telephone industries 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 (non-foggy) tariff complexity to evaluate how competition affects the use of deceptive and non-deceptive pricing strategies as entry of competing firms occurs exogenously in several local and independent markets.

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 incumbents 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 allows for a richer 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 almost by the same proportion. This opposite strategy continues even when we consider the possibility of individual uncertainty regarding future usage. For low levels of uncertainty, *i.e.*, when individuals are accurate predicting their future consumption, incumbents do not increase tariff fogginess and

²³ 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 paper.

entrants do reduce it. 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 bad at predicting their future usage, but in all cases entrants always offer less foggy tariffs than incumbent firms. All other results reported in the paper are robust to the existence of individual heterogeneity regarding uncertainty and usage of cellular telephone services.

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