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Quantifying the Benefits of Entry into Local Phone Service

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Abstract

In this paper, we evaluate the consumer welfare effects of entry into residential local phone service in New York State. Residential local phone service competition was an important goal of the 1996 Telecommunications Act. We provide a detailed evaluation of its effects on consumer welfare using household-level data on service choices from the third quarter of 1999 to the first quarter of 2003. Our results indicate that as a result of entry households that subscribe to one of the entrants' services gain on average an equivalent of $2.33 per month in overall welfare from local telecommunications services, or 6.2% of the households' average bill. Averaged across all households including those that remain with the incumbent, households gain the equivalent of $0.83 per month, although benefits vary dramatically across households. Since residential local phone service is sold under a menu of nonlinear tariffs, we develop a method for estimating a mixed discrete/continuous demand model. The econometric model incorporates the simultaneity of the discrete plan and continuous consumption choices by consumers. We allow for flat-rate plans, bundling of services, and unobservable firm quality. Taking advantage of the detailed nature of the data, we decompose the households' overall gains from entry and find that benefits due to firm differentiation and new plan introductions exceed those from price effects.

Keywords: Entry, Nonlinear Pricing, Telecommunications, Discrete/Continuous Demand.

JEL Classification: D43, K23, L11, L13, L96

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1 Introduction

Many countries, including Australia, Canada, the European Union's (EU) member countries, Japan, South Korea, and the U.S., require incumbent telephone companies to provide new entrants access to individual elements of their network infrastructure at regulated rates, a practice commonly referred to as "unbundling." Regulators have imposed such requirements as a means to create competitive telecommunications markets and benefit consumers through adoption of new services. In this paper, we study the consumer welfare implications of unbundling policies in the U.S. using a household-level data set from New York State. Possible welfare effects, over the length of the time period of our study, derive from price reductions, innovations in service offerings, and differences between incumbents' and entrants' services.

In the U.S., the markets for local residential and business telephone service were opened to competition following the 1996 Telecommunications Act (the 1996 Act). The 1996 Act allows three forms of entry: replication of the incumbent's infrastructure, lease of the incumbent's existing infrastructure (unbundling), or resale of the incumbent's services. By the late 1990's, competitive local exchange carriers had begun service in most U.S. states, mostly through leasing unbundled infrastructure or reselling service. As of December 31, 2003, entrants leased 60.6% of their residential and business lines and another 16.0% involved the resale of an incumbent's services (Federal Communications Commission 2004).

We evaluate the consumer welfare effects of entry in New York State by quantifying the effects based on actual consumer choices. Although there are a few other estimates of the expected savings by U.S. consumers as a result of entry into local phone service (see Telecommunications Research & Action Center 2000 and 2001), these rely on hypothetical consumer migrations and ignore geographic differences in providers' service offerings. Instead, the household-level data that we utilize allows us to model geographic variations in service offerings as well as individual choice behavior using detailed demographics, thereby permitting a distinction between welfare effects generated by lower prices, increased product variety, and firm-level differentiation.

Residential local phone service is sold under a menu of two- or three-part tariffs in which consumers choose a plan with a monthly fee and their usage based on a per-unit price. Such mixed discrete/continuous choices also occur in other markets such as energy, information and Internet access. Hanemann (1984) provides a methodology for estimating econometric models that link the discrete and continuous choices in the same utility maximization problem. We expand his framework along several dimensions. Our utility specification allows for flat-rate plans at zero marginal prices, bundling of multiple services under one plan, unobserved vertical quality differences across firms, and horizontal firm differentiation to account for the fact that some households switch carriers despite higher prices while others do not. We employ a maximum likelihood estimation technique that combines the information from the discrete and continuous choices by consumers. Our analysis focuses on the demand effects of entry only since regulation of incumbent prices for both the shared infrastructure and final services effectively limits the role of supply-side responses.

We estimate our model using data from a random sample of New York households over a three and a half year period beginning in late 1999. We focus on New York because it was one of the first states to experience entry under the 1996 Act. Significant entry occurs by the end of our sample period with entrants serving over 20% of the access lines. The largest entrants are AT&T and MCI, which comprise approximately 85% of the residential lines served by entrants. They compete with the incumbent, Verizon, whose customers are also included in the analysis.

Applying our econometric model to the household-level data, we are able to quantify the full distribution of welfare effects of entry. We find that these effects differ dramatically across households, underscoring the need for an individual-level analysis. The addition of the entrants' plans to the choice set leads, on average, to household gains of $0.83 per month, or 2.5% of households' average monthly bill. The standard deviation of welfare gains across households is $3.42, with average gains of $2.77 and $1.13 accruing to AT&T and MCI subscribers respectively.

Exploiting the detailed household-level data, we decompose the different sources of consumer benefits from entry and determine who gains the most from unbundling. The entrants introduce several new plans not offered by the incumbent. We find that considerable gains to consumers result from these new plan varieties. The introduction by AT&T and MCI of a flat-rate plan previously unavailable in New York City entails a welfare increase of $0.68 per month on average, while AT&T's introduction of a combined local and regional calling plan results in a welfare increase of $0.21 per month on average across all households.

Although the entrants employ the same technological infrastructure as the incumbent, their end-services are vertically and horizontally differentiated due to non-technological factors, such as customer support and marketing. Observed and unobserved firm effects play an important role in households' choices. Prior experience with an entrant's long distance services is particularly important, suggesting that households consider a prior relationship in forming their assessment of the entrant's local service quality. We find that AT&T households enjoy monthly benefits of $1.84 per month from such differentiation, while MCI households receive monthly benefits of $0.64. This compares to savings of $1.15 and $0.40 over what the average AT&T and MCI household, respectively, would have paid on Verizon based on pure price effects alone. Thus, a focus only on prices, disregarding firm differentiation, significantly understates household welfare gains.

Relating household-level welfare benefits to household characteristics, we find that larger households in New York City benefited more from entry, presumably due to the entrants' introduction of new flat-rate plans there. The fact that high-usage households, which on average are lower-income, black, and larger, gained more than other households suggests that competition intensified primarily for high-valuation customers. Customers of the entrants' long-distance services also gained more, consistent with the importance of horizontal firm differentiation.

Our results are particularly interesting because, according to the provisions of the 1996 Act, incumbents and entrants were to compete starting with identical inputs and on an equal footing. Our finding that entrants offer differentiated services and introduce meaningful plan innovations is thus important for quantifying the benefits of regulatory measures to increase competition when entrants and incumbents share infrastructure. We find that these effects are more important than the pure price effects. This is consistent with results in Greenstein and Mazzeo (2006) who find that entrants' initial market selection depends on differentiation strategies, in addition to factors such as demand and cost differences across markets, economies of geographic scope, and regulatory stringency highlighted by Crandall and Sidak (2002) and Zolnierek, Eisner and Burton (2001).

In March 2004, the D.C. Court of Appeals reversed the Federal Communication Commission's implementation of unbundling policies on the grounds that the absence of nationwide access to local loops at "cost plus reasonable profit" did not "impair" entrants as the 1996 Act required. As a result, the largest entrants stopped accepting new customers (see Economides 2005 for more detail). Despite the short-lived effects of unbundling in the U.S., the experience through 2004 is instructive for several reasons. First, it offers a unique opportunity to inform decisions of whether to initiate or continue unbundling policies in local telecommunications markets in other countries as well as in other settings. These include unbundling cable modem Internet access, presently awaiting implementation in Canada, cable television service, under consideration in the Netherlands, and DSL Internet access, mandated by the EU's 2000 Unbundling Regulation. Second, the detailed U.S. data available allows an assessment of the economic implications of unbundling policies, such as the sources and magnitudes of any welfare gains and the types of households who are likely to benefit. Although the specifics of settings differ, our results suggest that initiatives to promote unbundled access in other countries should consider broader implications beyond price effects.

2 New York's Local Telephone Markets

New York has two sizeable incumbents, whose geographic territories are displayed in Figure 1. Frontier Communications of New York controls 8% of incumbent business and residential access lines as of December 31, 2001, while Verizon, the focus of our analysis, controls 89%. The 1996 Act introduces local telecommunications competition in Verizon's region, which had not previously opened its markets to competition.

The New York Public Service Commission (NYPSC) serves two roles in regulating the local phone market as it relates to our study. First, it sets infrastructure lease rates that entrants pay to the incumbent. These rates remain stable during our sample period with the exception of a decrease of about 30% in July 2002. The lease rates vary by geographic zone within the state, averaging approximately $20 per line served as of early 2001 and falling to approximately $15 by the middle of 2002.[1] Second, the NYPSC regulates the retail rates that incumbents charge for local phone services. We describe the retail prices faced by customers in our sample in greater detail in Section 3.

The entrants' market share of residential lines increases steadily from 6% in 1999 to 22% in 2002. The main entrants in New York during our sample period are AT&T and MCI, both of which expand into local service from the long-distance market. As of December 31, 2001, AT&T and MCI hold shares of 58% and 27%, respectively, of residential lines served by entrants in New York. AT&T's initial entry into New York occurs in late 1999 and focuses on the state's metropolitan areas, as displayed in Figure 2. In 2001, AT&T enters into the remainder of Verizon's territory. MCI enters Verizon's entire territory in 1999.

By 2001, each of the three carriers offers three types of phone service: local, regional, and long-distance. Local service applies to phone calls in the household's local calling area. Local calling areas are defined identically for the carriers and differ significantly in the population served, ranging from 1,873 people in Indian Lake to 7.98 million people in New York City, with an average of 304,597 people. Local calling areas are grouped into seven regional calling areas. Calls within these regions and outside of the household's local calling area are, in general, handled by the local service provider, but carry additional charges. All remaining calls qualify as long-distance calls. While the incumbent, Verizon, began offering long-distance service in 2001, long-distance service was provided primarily under separate calling plans from local and regional calls during our sample period. As a result, we concentrate on estimating the benefits from competition in local and regional service.

The carriers provision local and regional phone services through monthly calling plans, of which three types are available to New York customers. Metered plans include a monthly fee to obtain service and a per-call fee for usage. Flat-rate plans specify a monthly fee for unlimited calling. Hybrid plans are three-part tariffs where a household pays a monthly fee to obtain a certain number of calls at zero marginal price. For calls above the pre-defined allowance, the household pays a positive marginal price. The FCC requires local carriers to offer additional calling plans at reduced rates to qualifying low-income households.

Local phone service providers also offer add-on features, such as call waiting, call forwarding, three-way calling, and speed dialing, to their customers. During the time period of our study, the carriers do not bundle these features with local or regional

[1] Based on Appendices 2 and 3 in http://www.cad.state.wv.us/Intro%20to%20Matrix%201-02.htm. The cost figures assume 1000 minutes of usage per month and incorporate discounts for leasing all network elements.

service. Instead they offer them as optional features that can be purchased along with basic service.

3 Data

We analyze plan choice and usage behavior using data on a sample of New York households collected by TNS Telecoms (TNS), complemented with data on the geography and structure of local telephone markets from various sources. TNS' Bill Harvesting data contains survey data from residential customers. TNS gathers demographic information on the households and asks them to submit their actual phone bill. Since willingness to respond varies by household characteristics, TNS employs over-sampling to obtain a random sample. Most households participate in the survey only once. Our sample runs from September 1999 through March 2003 and covers a total of 7,222 cross-sectional household observations.

For each household, the data set contains information on its local carrier choice and any detailed line items recorded on its local telephone bill, including the services the household purchased, total amount paid, and a breakdown of the bill into services, fees, and regulatory charges. For households that subscribe to metered service or exceed their call allowance on a hybrid plan, we observe the number of calls made during the billing period. Local usage is generally not available for the remaining households, notably those on flat-rate plans.

The TNS data does not directly identify the calling plan chosen by the household. Instead, we use descriptions of purchased services and associated expenditures to uniquely identify the household's chosen calling plan based on publicly available information. The NYPSC requires all carriers to publicly file retail price information whenever prices change, allowing us to construct the universe of calling plans and their prices at all times during our sample period. Most local plan characteristics aside from prices remain unchanged during our sample period. Since providers adjust consumers' bills to reflect price changes as they go into effect, we identify each household's plan among contemporaneous plans. Across providers, we are able to match 97.2% of households to a calling plan.

Since AT&T and MCI did not enter into Frontier Communications' territory, we focus on households who reside in Verizon's territory. We use the household's location, available at the zip-code level, together with detailed data on the availability of AT&T and MCI's local service within Verizon's territory, to construct the household's choice set of local service carriers and plans at the time of its bill. We employ the Center for Communications Management Information's QTEL Local Calling Area Database, which maps the first six digits of a telephone number to the set of telephone numbers that can be called locally, to identify each household's local calling area based on its telephone number. To measure the size of the potential calling area for local and regional service, the "coverage area", we use mapping software to measure the calling area's population based on the 2000 Census.

Of the 7,222 households in the sample, 696 subscribe to AT&T, 931 to Frontier Communications, 362 to MCI, and 5,233 to Verizon. The remaining 547 households subscribe to other, small carriers and, together with Frontier's customers, are excluded from the sample. The entrants' representation in the sample is similar to aggregate market shares for New York. In 2001, for example, the NYPSC reports market shares based on number of lines of 11.8% and 5.6% for AT&T and MCI respectively, while in the TNS sample for the same year, 12.2% of households are AT&T customers and 5.4% are MCI customers. Due to missing information, reporting errors by TNS, or other data issues, we are not able to use all available observations in our estimation. The sample observations with complete demographic and usage information total 592 (85%) for AT&T, 218 (62%) for MCI, and 3,981 (76%) for Verizon.[2]

The TNS data contain information on the households' basic demographic profile as well as use of other telecommunications services and technology products summarized in Table 1. Household size and income are likely the strongest proxies for demand for usage. The household's income is reported as a categorical variable. To transform it into a single continuous variable, we assign to each household an income equal to the predicted average income level in its category, as described in more detail in Appendix 8.1. Compared to the state's aggregate distribution, the income distribution is slightly skewed towards lower income households. Other demand shifters include whether the household moved in the past year and had to choose a new service provider, whether at least one member of the household subscribes to cellular service, and whether the household has access to the Internet at home.

Table 1 displays the households' long-distance provider choices in relation to their local provider choices. Across all firms, 38.8% of households uses the same provider for local and long-distance service. This fraction is significantly higher for entrants, however; 88.5% of AT&T customers and 85.3% of MCI customers subscribe to these providers' long-distance services. In the data, we also observe whether households receive a single bill for local and long-distance service. Verizon offers households an option to request that their long-distance service be billed through the incumbent on a single bill regardless of long-distance provider. Of the households who use Verizon's local service, 76.3% elect this co-billing option. The entrants offer a similar service for a charge of $1.50 per month. Of the households that use AT&T and MCI's local services, 97.0% and 94.4%, respectively receive the same bill, either because they use the same firm's long distance

[2]Reasons for excluding observations include the household subscribing to a plan that is unavailable to the population at large, being billed for a partial month, switching plans in the middle of a month, or having multiple phone lines. We further exclude households on calling plans that bundle long-distance and local service in the same plan, which occurs for only 52 observations. Based on the bill-level data alone (ignoring demographic information), the usable observations include 601 AT&T, 218 MCI, and 5,021 Verizon households.

service or pay the \$1.50 charge.

Some simplifications of the data are necessary to make estimation tractable. Depending on the chosen plan, carriers bill usage either in terms of minutes or calls. Charges may vary by time of day, length of call, or, in the case of regional service, distance of call. We convert all usage information to a per-call basis, using the empirical average call length in minutes and the empirical distributions of intra-day calling patterns and call distances to construct measures of numbers of calls and weighted average per-call prices. In the remainder of the paper, we ignore within-call non-linear pricing and the household's choice of timing of individual calls or distance of calls made. Ignoring within-call non-linear pricing could bias our results if, for example, certain customers' preferences for making many short calls steer them to a provider that bills on a per-minute rather than a per-call basis. Descriptively, however, the data do not suggest that households' call durations and their call distributions over the course of the day differ significantly across carriers, providing some evidence that the role of within-call non-linear pricing in determining households' plan choices is limited.

Typically, each carrier offers one metered plan and one flat-rate plan for local calling. Regional calling is generally billed on a per-call basis. There are several exceptions to this. From 1999 until September 2000, MCI offers an additional hybrid plan for local service. Only AT&T offers flat-rate service to New York City customers during the entire sample period, while MCI introduces this option in September 2000 and Verizon does so only after the end of our sample period. In addition, AT&T offers a calling plan that bundles local and regional services into a hybrid plan with a single price for both local and regional calls in excess of the joint call allowance, the only true bundle of services available during the sample period. On average, households have a choice of six calling plans across providers, ranging from three plans in areas where AT&T entered only in 2001 to eight in areas where all three firms operate.

Under the NYPSC's regulation, Verizon holds basic service prices constant from at least September 1, 1995 until September 2000 and reduces them thereafter. Verizon thus does not change its pricing as an entry-deterrence strategy. In parallel with the 2002 decrease in wholesale lease rates, the NYPSC grants Verizon a retail rate increase. Verizon's prices for local metered and regional service differ for metro and non-metro regions and prices for flat-rate service differ across five geographic areas. AT&T and MCI employ a simpler pricing strategy, charging a single price to all metered customers and differentiating pricing of the flat-rate plan only between metro and non-metro regions.

Table 2 summarizes the plan choices and prices paid by households in the sample. A large share of customers, 47.5%, subscribes to metered service, which reflects in part that in New York City, this is frequently the only type of service offered. Verizon's metered service on average dominates its competitors' offerings on price: the average fixed fee paid by Verizon households is only \$5.99, compared to \$8.21 and \$6.27 for AT&T and MCI, respectively, while Verizon's average per-call charges fall short of its competitors' prices by approximately \$0.01. Similarly, Verizon's flat-rate customers pay lower fixed fees on average than their AT&T and MCI counterparts. Due to varying choice sets across households and additional charges beyond basic service charges, these statistics do not imply necessarily that Verizon is the lowest-cost option for all households in its territory. Nevertheless, they raise the question of which considerations apart from price drive a household's carrier choice, which we investigate in Section 4.

4 Consumer Response to Entry

A usual difficulty in assessing the effect of entry is controlling for the incumbents' response. In our setting, we take advantage of the fact that incumbents' prices, both for services and infrastructure leases, and service quality[3] are regulated. Since the entrants primarily lease the incumbent's infrastructure, the industry's overall cost structure remains relatively unchanged over the time period we analyze, aside from possibly increased marketing expenditures and service costs (such as operator service) by firms.

While entry obviously entails changes in and a reallocation of industry profit, we focus on demand-side responses to changes in the carrier set, instead of conducting a full welfare analysis of entry. We consider several possible effects of entry on consumer welfare, including pure price effects (holding usage quantity and service quality constant) and horizontal and vertical differentiation effects resulting from the increased number of provider or plan choices.

Even though bundling of local and long-distance service in a single plan is rare during our sample, we recognize two ways in which the household's long-distance carrier choice is relevant to consumer welfare. First, the entrants offer discounts to households that choose them for both services. This discount is \$1.00 for AT&T during the entire sample period and \$4.95 for MCI from August 1999 to August 2000 only. We account for this in our estimation of the price effects. Second, households may place value on receiving a single telecommunications bill for both services, providing an additional incentive to choose the same local and long-distance provider.

We begin with an assessment of the pure price effects from entry, by computing the cost savings that households realize from the choice of an entrant's service over the incumbent's offerings, holding household usage constant. We then turn to providing evidence of the role that non-price effects play in the demand for local service, as a motivation for the econometric model discussed in Section 5.

[3]The NYPSC requires Verizon to tabulate eight service quality measures on a monthly basis, including customer trouble report rate, out of service rate, repair and installation times. Failing to meet service quality standards results in penalties.

4.1 Monetary Effects of Entry

Abstracting from usage responses and quality differences among firms, we compute the effect of entry by simply determining how much consumers in the Verizon region (in which AT&T and MCI entered) save from the presence of the entrants. We evaluate the amount of money that AT&T or MCI local service customers would pay to Verizon in the absence of the entrants' services. This requires mapping the household to a specific Verizon plan based on its usage and evaluating the amount it would pay to Verizon under that plan, relative to its actual payment to one of the entrants.

We make several assumptions in this counterfactual. Since we do not observe the length of time a household has been with a carrier, our comparisons are contemporaneous. For example, for a household that uses AT&T in January 2001, the hypothetical choice set includes Verizon plans available at that same time. We assume further that households choose the optimal plan, both among the entrants' offerings and in the counterfactual among Verizon's offerings. We discuss the validity of this assumption below. If a household chooses an entrant's flat-rate service, we compare it with its expenditure on a flat-rate plan from Verizon, if available, since we generally do not observe usage for such households. If Verizon flat-rate service is not available, for example in New York City, we base charges on the household's estimated usage conditional on its usage exceeding the break-even point between the entrants' metered and flat-rate services.[4] Of these assumptions, only the assumption of optimal plan choice carries through to the remainder of the paper.

Table 3 presents the results of the counterfactual with savings divided by source. On average for the same usage, AT&T customers save \$1.15 per month relative to subscribing to Verizon's optimal contemporaneous plan. Of this, \$0.89 on average is due to buying both long-distance and local service from AT&T, representing the 89% of AT&T sample households that receives the \$1 long-distance discount. Another \$0.53 arises from savings on add-on features. As suggested by the price patterns in Table 2, households on average lose money on combined basic charges for local and regional service by using AT&T.

The results for MCI are similar although households save less on average. The mean household saves \$0.40 per month on its bill relative to subscribing to Verizon's optimal contemporaneous plan. The average household loses money on combined basic and regional charges as well as on add-on features. Households benefit on average by \$1.07 from discounts for subscribing to both local and long-distance service from MCI.

The counterfactual abstracts from quantity responses in moving to the optimal plan. This implies that for households who realize an increase in the per-call price on

[4] A second instance where Verizon's offerings do not match the entrants' offerings arises for AT&T's bundled local and regional service. In this case we assume that the households would choose Verizon's flat-rate plan for local usage and estimate regional charges based on average regional usage for the remainder of the sample.

the optimal plan, we underestimate the true extent of savings. For households with a decrease in the per-call price, however, the effect on savings is unclear: they save on pre-existing usage, but also expand their usage in total in response to the lower price.

AT&T and MCI engage in additional "off-plan" promotional activities to induce households to choose their service. Under the majority of such promotions, qualifying households receive a discount applied to their bill for a certain number of billing periods. Based on a comparison of data on AT&T and MCI's off-bill promotions during the sample period to the households' bills, none of the subscribers in the sample receive such bill credits. To the extent that households benefit from less common off-bill promotions, any consumer welfare gains in this paper represent a lower bound.

4.2 Heterogeneity in Cost Savings and Possible Explanations

The average household savings on AT&T and MCI mask significant heterogeneity across households. Out of 592 AT&T households in our sample, 331 households (56%) save money by choosing AT&T. Monthly savings for these households amount to \$5.39 on average and \$4.44 at the median. The vast majority is on one of AT&T's flat-rate plans (61.8% on local flat-rate service and 30.7% on bundled local and regional service), including 86 households in New York City where Verizon does not offer flat-rate service. The remainder of AT&T subscribers incurs a higher bill, paying on average \$4.24 or 22% more than their expected payment to Verizon. 81.2% of these households also subscribe to AT&T's local flat-rate plan, but only 3.8% use AT&T's bundled local and regional plan.

Out of the 218 MCI households, 63.8% save money by choosing MCI with average monthly savings of \$3.24 and median savings of \$2.25. The remaining MCI households incur additional charges of \$4.59 or 19% of the price they would pay on Verizon. The propensity to incur such additional charges differs by plan type. Only 29% of households on a metered plan and 34% of households on a hybrid plan overpay by choosing MCI compared to 54% of households on flat-rate service.

We also compare bill amounts of households that use Verizon for local service to the expected bill from AT&T or MCI for their realized usage. Verizon's service is on average \$1.68 or 3.8% cheaper than equivalent charges on the least costly, contemporaneous plan offered by one of the entrants. We again find significant heterogeneity in savings across households with 40% of households losing \$3.85, on average, by not leaving Verizon.

There are a number of reasons why a household may choose a particular carrier even though it is not the cheapest provider. Inertia or high deliberation costs of evaluating the prices of various calling plans could lead consumers to keep a more expensive plan. Since all subscribers start out as Verizon consumers, inertia would lead to such instances being more frequent among households that remain with Verizon even after the introduction of the entrants' service.

A second explanation lies in demand uncertainty. Since the household commits to a provider and a plan before making calls, the household's choice may be optimal based on expected usage, but unpredictable demand for calls causes the plan choice to not be the least expensive ex-post. Miravete (2002a) studies the effect that uncertainty over usage has on the initial plan choice. He finds that consumers make, on average, the correct plan choice conditional on their realized consumption, despite their uncertain usage, and that consumers frequently switch calling plans with the goal of minimizing cost of service in response to small differences in cost.[5] While demand uncertainty represents a rational explanation for the choice of a more expensive plan, DellaVigna and Malmendier (2006) suggest that certain consumers systematically over- or under-predict usage, which firms may exploit in their pricing strategies to lock these consumers into suboptimal plans.

A last explanation is quality differentiation by firms, whereby any overpayment represents the consumer's willingness to pay for higher quality of service or firm reputation. Since the entrants lease Verizon's infrastructure and add-on features, the quality of call provision is similar across firms and regulated by the NYPSC to prevent service deterioration.[6] Firms are differentiated primarily in their customer service quality and in the variety of calling plans offered. In addition, consumers may have perceptions of the carriers' quality based on prior experience with the entrants' long-distance services.

We provide several forms of evidence of the drivers of household carrier choices, which inform our econometric model in Section 5. We begin with simple tabulations of the frequencies and magnitudes of household overpayments for local service, relative to the cheapest option available during the household's billing period. Table 4 summarizes the overpayments normalized by the cost of the least expensive option, distinguishing between households that could realize savings by switching carriers and those that could do so by simply switching to a different plan by the same provider. To assess the latter, we evaluate whether households on metered service would pay less on the provider's flat-rate plan, if available, given their monthly usage.

The share of households with potential savings from adjusting their provider choice, approximately 40% across providers, far exceeds the share of households that could save from switching among the chosen provider's plans with t-statistics for tests of differences in mean frequencies of 5.85 for AT&T, 4.66 for MCI, and 19.35 for Verizon households. The magnitudes of the potential savings, however, are similar. Of AT&T

[5] His findings contradict earlier work (Hobson and Spady 1988, Kling and van der Ploeg 1990) that documents that a significant fraction of customers appear to show a bias towards subscribing to a flat-rate option, even if their usage is too low to justify the choice rationally. Most of this evidence comes from data collected shortly after the introduction of optional local metered service and, as Miravete (2002a) argues, such biases may result as a transitory side effect of understanding a new plan choice.

[6] There is little evidence of competition through innovation in or variety of add-on features. During the time period of our sample, Verizon does not introduce significant new add-on features, nor do we observe differences in the variety of add-on features bundles offered across providers.

households with potential cost savings, 87% choose AT&T's flat-rate plan despite the availability of Verizon's lower-priced flat-rate service, while among the corresponding group of MCI households, 20% choose flat-rate service in areas where Verizon offers a lower-cost flat-rate option. The fact that a household's choice of calling plan among its carrier's offerings is frequently correct, relative to its choice of carrier, suggests that demand uncertainty or consumer irrationality are not very significant in biasing the choice of plan. Further, we interpret this as evidence that perceived differences in provider quality influence the household's provider choice, in particular for households that choose flat-rate service, which eliminates any effect of unexpected demand fluctuations on price paid. Table 4 also provides evidence that consumer inertia in decision-making does not play a major role. Households who choose AT&T, for example, are more likely to overpay for their service than Verizon households, even though their choice indicates a willingness to search for a new provider and less inertia than the Verizon households.

We now investigate characteristics of households who do not choose the least-expensive provider in a probit model. In addition to demographic characteristics, we control for prior experience that the household has with AT&T or MCI by including indicator variables for whether the household uses AT&T or MCI for its long-distance service.[7] Table 5 displays the results of this probit model, allowing the coefficients to differ across chosen carrier.

There are few characteristics that predict the household's likelihood not to choose the least-expensive carrier. Households that moved in the last year are statistically and economically less likely to overpay for local service, possibly contradicting the finding above that inertia is not significant in driving household biases. Diverging results emerge for most other demographic characteristics. While Verizon's minority households are statistically more likely to overpay as a result of their carrier choice, their AT&T counterparts are statistically less likely to do so. Similarly, larger households, possibly experiencing larger demand fluctuations, are more likely to choose MCI erroneously, while the opposite holds for Verizon. Overall, the variances explained by the probit models are very low with likelihood ratio indices of 0.09 for AT&T households, 0.19 for MCI households, and 0.13 for Verizon households,[8] providing little evidence of suboptimal choice behavior by certain demographic groups or successful targeting by the providers of consumers based on observable characteristics.

The probit regressions also control for seasonality that induces demand variation over months. If the seasonal controls explained a large share of the variance, it would be an indication that households choose calling plans based on expected usage over the course of the year as opposed to adjusting their plan choice in response to seasonal variation in usage (as we assume in our model in Section 5). The monthly dummies

[7] We thus assume that households made their long-distance provider choice of AT&T or MCI prior to choosing the carriers as their local service providers.

[8] We use McFadden's (1974) likelihood ratio index, defined as $LRI = 1 - \frac{ln[L_1]}{ln[L_0]}$, where L_0 is the log-likelihood computed with only a constant term and L_1 is the log-likelihood of the full model.

only account for an increase in the likelihood ratio index from 0.06 to 0.09 for AT&T customers, from 0.13 to 0.19 for MCI customers, and from 0.11 to 0.13 for Verizon customers. It appears that anticipated seasonal demand fluctuation are, therefore, not very important in driving provider choices.

To test for the importance of consumer learning, in an alternative unreported model, we include time since the entrants' inception of service and time since a price change, both measured in days, as explanatory variables. The results indicate that for every 100 days since AT&T's entry, a household's likelihood of erroneously choosing AT&T decreases by 2.0%, providing statistically significant evidence of some extent of household learning. The overall explanatory power of the model does not improve significantly, however, resulting in a likelihood ratio index of 0.11. For MCI, in contrast, the probability of mistakes in the provider choice increases by 3.80% for every 100 days since MCI's entry. Across providers, thus, we do not find consistent, practical significance of learning.

As a last piece of descriptive evidence of determinants of carrier choice, we estimate a multinomial logit model of provider choice, using Verizon as the base category. The results are in Table 6. Relative to the small variance in households' incorrect provider choices explained above, household characteristics explain a significant fraction of the variance in choice behavior with a likelihood ratio index of 0.41. Several characteristics, such as income, household size, and race, are statistically but not practically significant in explaining a household's decision to switch to an entrant. Most significant, both statistically and economically, is whether the household has prior experience with the provider through a subscription to its long-distance service and whether the household receives a common bill for its local and long-distance service, but uses two different providers. Households with AT&T as their long-distance provider are 35.3% more likely to choose AT&T as their local provider, while the equivalent figure is 42.2% for MCI. The results are consistent with a number of interpretations including the entrants marketing their local service more aggressively to pre-existing long distance customers, consumer benefits from receiving a single bill, and perceived quality differences that induce household sorting into providers. The last possibility suggests possible strategic benefits from bundling the two services. Households that receive a single bill but utilize different service providers are less likely to switch to an entrant, reflecting the fact that they incur charges from the entrants for this convenience while Verizon, due to regulation, offers this service at no additional charge.

Taken all together, these results are consistent with households that already use one of the entrants as their long-distance provider attributing a higher perceived quality to that firm than other households. Since the evidence points toward differences in firm quality as contributing to suboptimal provider choices across households, we allow for firm differentiation effects in our econometric model and ignore inertia and demand uncertainty as being of second-order importance only.

5 Demand Model

In estimating local telecommunications demand, the presence of nonlinear tariffs has been accommodated in several ways. Train, McFadden and Ben-Akiva (1987) employ a nested logit structure to estimate demand for local phone service in which each nest is a combination of a plan and a portfolio of calls (number and distance). The immense number of possible portfolios limits the applicability of the technique. Miravete (2002b) instead infers the distribution of consumers' utility for local phone calls by incorporating the time lag between the initial plan choice and the subsequent usage decision. He identifies differences in the distribution of consumer types before and after a change in plan offerings and analyzes the extent of usage-based discrimination by the local phone company.

A second strand of the literature models local telecommunications demand as a mixed discrete/continuous model, building upon earlier empirical work by Dubin and McFadden (1984), Dubin (1985), Chiang (1991) and Chiang and Lee (1992). One example is the study of local phone service penetration by Hausman, Tardiff and Belinfante (1993). Due to lack of usage data, they estimate only the discrete portion of the model, but incorporate in it the usage choice consistent with utility maximization. Narayanan, Chintagunta and Miravete (2007) use a model similar to ours to study the extent of consumer learning about usage after a new plan introduction. In contrast to their setting, the types of available calling plans remain virtually unchanged both prior to and during our sample period and any consumer learning is therefore likely to have occurred already. Instead, we focus on the effect of competition on consumers' plan and usage choices and explicitly model bundling of local and regional calling as two potential sources of welfare gains for consumers.

5.1 Household Choice Problem

We consider households indexed by $i = 1, 2, ..., I_h$ in $h = 1, 2, ..., H$ markets. The households choose a plan from the set of available plans, indexed by $j = 1, 2, ..., J_h$, offered by firms $f = 1, 2, ..., F_h$, and the quantity of local calls q_{ij}^L and regional calls q_{ij}^T they consume on the plan. To consume on plan j, consumers must pay a fixed fee, P_{jh}, a per-call local price of p_{jh}^L and a per-call regional price of p_{jh}^T. Consumers spend the remainder of their income on an outside good z. Since approximately 95% of New York households subscribe to landline telephone service to their home and less than 3% of cellular subscribers had fully displaced their landline by March, 2002, we do not incorporate the outside option of not subscribing to telephone service. Lack of data on cellular usage beyond ownership also forces us to abstract from possible substitution between cellular and landline usage.

Households have a choice of up to three types of plans per carrier: metered, flat-rate, and hybrid plans. On a metered plan, households pay $p_{jh} > 0$ per call regardless of total usage and pay a fixed fee of $P_{jh} \geq 0$. On a flat-rate plan, consumers pay nothing for usage ($p_{jh} = 0$) but incur a fixed fee of $P_{jh} > 0$. On hybrid plans, households pay a fixed fee $P_{jh} > 0$ and pay nothing ($p_{jh} = 0$) for usage below a threshold $\tilde{q}_{jh}$ but pay $\tilde{p}_{jh} > 0$ for usage above $\tilde{q}_{jh}$. Due to the fixed fee and the fact that local and regional services are bundled within a firm, it is optimal for the household to consume on a single plan j.

We assume that household i chooses that plan j that maximizes its utility subject to the budget constraint:

$$\begin{aligned} u(q^L_{ij}, q^T_{ij}, z_i) &= z_i + \frac{1}{b^L}\left(a^L_i q^L_{ij} - \frac{(q^L_{ij})^2}{2}\right) + \frac{1}{b^T}\left(a^T_i q^T_{ij} - \frac{(q^T_{ij})^2}{2}\right) \\ &\quad -\frac{\left(a^L_i\right)^2}{2b^L} - \frac{\left(a^T_i\right)^2}{2b^T} + \zeta_{ij} + \epsilon_{ij} \\ &\quad a^L_i, a^T_i, b^L_i, b^T_i > 0; q^L_{ij} \leq a^L_i, q^T_{ij} \leq a^T_i. \end{aligned} \tag{1}$$

s.t.

$$y_i \geq z_i + P_{jh} + p^T_{jh} q^T_{ij} + p^L_{jh} q^L_{ij}(1 - I^H_j) + \tilde{p}^L_{jh} \max\left(q^L_{ij} - \tilde{q_{jh}}, 0\right) I^H_{jh}.$$

In Equation 1, the first term represents the utility obtained from the outside good whose price is normalized to one. The second and third terms measure the utility obtained from local usage and regional usage, respectively, as a function of the demand parameters a^S_i and b^S_i. ζ_{ij} is household i's perceived quality of plan j net of an unobserved household preference for plan j. ϵ_i is a $J \times 1$ vector of unobservable plan preferences, which we assume to be distributed according to a Type 1 extreme-value distribution. The budget constraint incorporates the within-plan nonlinear pricing of hybrid plans ($I^H_{jh} = 1$) via the call allowance, $\tilde{q_{jh}}$. Regional calls are not offered using standalone hybrid plans in the data. Conditional on the choice of plan j, the associated conditional demand function for usage of type S, $S = \{L, T\}$, is given by:

$$q^S_{ij}(p^S_{jh}) = \begin{cases} a^S_i - b^S p^S_{jh} & \text{if } p^S_{jh} < \frac{a^S_i}{b^S} \\ 0 & \text{otherwise.} \end{cases} \tag{2}$$

Note that if a household chooses a flat-rate plan, with a marginal price for usage of $p_{jh} = 0$, or a hybrid plan where it remains within the included number of calls, $\tilde{q_{jh}}$, the demand function simplifies to:

$$q^S_{ij}(p^S_{jh} = 0) = a^S_i. \tag{3}$$

We set the household's local usage on hybrid plans equal to the allowance $\tilde{q}_{jh}$ if the household's optimal quantity based on Equation (2) at $\tilde{p}^L_{jh}$ falls short of the allowance, but the optimal quantity based on a zero per-call price (Equation (3)) exceeds the allowance.

Substituting these conditional demand functions into the household's utility function yields a set of conditional indirect utility functions that vary depending on the household's choice of plan and usage patterns. For household i with positive usage of local and regional service, the conditional indirect utility function is given by:

$$
\begin{aligned}
v_{ij}(p^L_{jh}, p^T_{jh}, P_{jh}, y_i) \quad = \quad & y_i - P_{jh} - \left(a^T_i - \frac{1}{2} b^T p^T_{jh}\right) p^T_{jh} \\
& - \left(a^L_i - \frac{1}{2} b^L p^L_{jh}\right) p^L_{jh} \left(1 - I^H_{jh}\right) \\
& - \left(a^L_i - \frac{1}{2} b^L \tilde{p}^L_{jh} - \tilde{q}_{jh}\right) \tilde{p}^L_{jh} I^H_{jh} I^A_{jh} + \zeta_{ij} + \epsilon_{ij}.
\end{aligned}
\tag{4}
$$

The third and fourth terms in the indirect utility function cancel if the household chooses a flat-rate plan for local and regional service, respectively. The fifth terms applies only to a hybrid plan and only if the household consumes in excess of the allowance, or $(a^L_i - b^L \tilde{p}^L_{jh} > \tilde{q}_{jh})$, indicated by I^A_{jh}. Corner solutions arise in the data for regional calls. As shown in Table 2, 65.5% of households make no regional calls, whereas all households have some local usage. With zero regional calls, the indirect utility function is given by:

$$
\begin{aligned}
v_{ij}(p^L_{jh}, p^T_{jh}, P_{jh}, y_i) \quad = \quad & y_i - P_{jh} - \left(a^L_i - \frac{1}{2} b^L p^L_{jh}\right) p^L_{jh} \left(1 - I^H_{jh}\right) \\
& - \left(a^L_i - \frac{1}{2} b^L p^L_{jh} - \tilde{q}_{jh}\right) p^L_{jh} I^A_{jh} I^H_{jh} + \zeta_{ij} + \epsilon_{ij}.
\end{aligned}
\tag{5}
$$

We allow the demand intercepts, a^S, to vary as a function of the household's observable and unobservable characteristics. For the demand functions to be well-defined, we restrict a^S_i to be positive by specifying it as an exponential function of the household's characteristics:

$$
\ln(a^S_i) = \alpha^S + \alpha^S_D \, D_i + \nu^S_i, \tag{6}
$$

where α^S and α^S_D are parameters and D_i is a column-vector of characteristics for household i. We assume that household i's demand intercept contains an unobservable household taste for local or regional usage, ν^S_i. The vector ν_i captures unobserved household characteristics that affect demand for local and regional calls, such as the size of the household's network of contacts in the area. We assume that the unobserved characteristics $\nu_i = [\nu_i^L, \nu_i^T]'$ are identically distributed according to a bivariate Normal distribution with mean zero and variance-covariance matrix:

$$\Sigma_\nu = \begin{bmatrix} \sigma_L^2 & \rho\sigma_L\sigma_T \\ \rho\sigma_L\sigma_T & \sigma_T^2 \end{bmatrix}. \tag{7}$$

Equation (6) implies that the demand error, ν_i^S, equals:

$$\begin{aligned} \nu_i^S &= \ln(a_i^S) - \alpha^S - \alpha_D^S\, D_i \\ &= \ln(q_{ij}^S + b^S p_{jh}) - \alpha^S - \alpha_D^S\, D_i. \end{aligned} \tag{8}$$

Last, we decompose household i's perceived quality of plan j into observable plan characteristics and an unobservable firm-level characteristic by parameterizing ζ_{ij} as:

$$\zeta_{ij} = \lambda_f{}'\, Z_i + \xi_{fh}, \tag{9}$$

with λ_f denoting a $z \times 1$ vector of parameters. Demographic shifters, Z_i, control for horizontal preference differences for a provider among households, for example based on the household's experience with the provider for a different type of service. ξ_{fh} represents an unobserved contribution to firm quality, such as the quality of the provider's customer service. This characteristic varies at the level of the firm, but not at the level of the plan, and is the same for all households, representing a vertical attribute of the provider.

The unobservable components in a_i^S affect the quantity consumed, but the discrete choice only indirectly through the quantity choice. They vary only by household, but not by plan, through ν_i^S. The unobservable components ξ_{fh} and ϵ_{ij}, on the other hand, affect only the discrete choice and not the quantity choice since plans within the same firm offer access to the same quality of calls and customer service.

Similar to the discrete choice demand literature (Berry 1994, Berry, Levinsohn and Pakes 1995 and 2004, Goolsbee and Petrin 2004, and Nevo 2001), the firm-level unobservable, ξ_{fh}, captures unobserved quality differences between firms. The descriptive results presented above suggest that unobserved provider characteristics are important in driving household provider choices, which might be reflected in the prices charged by each provider. We model the unobservable as varying at the level of the firm only, instead of the level of the product, since calling plans are non-linear pricing schemes that give the customer access to the same customer and billing services and quality of calls. This allows us to control for price endogeneity by including provider/market fixed effects in the household's indirect utility function. Since the unobserved provider characteristics and prices vary at different levels of aggregation, we identify the unobserved characteristics from observing a large number of provider choices in each of the markets.[9]

Since add-on features represent a significant portion of savings from price effects, it is important that we accommodate them in the econometric model. There are too many possible combinations of add-on features offered to explicitly estimate their choice by households. Instead, we assume that each household consumes an identical bundle of add-on features regardless of which carrier or plan it chooses and adjust its budget constraint by the difference in prices for that bundle between the two firms.

Our modeling framework corresponds to that in Hanemann (1984) for the case of mutual exclusivity whereby each consumer chooses to consume a continuous quantity from a single provider. Our work thus complements a number of recent papers (Chan 2006, Dubé 2004, and Hendel 1999) that consider scenarios in which households choose an optimal number of discrete products or multiple discrete products (Kim, Allenby and Rossi 2002). While the quadratic utility function and the demand system implies a simple linear relationship between price and usage regardless of the price level, the utility function has several advantages compared to alternative specifications. It easily accommodates the following main features of the institutional setting. First, the specification allows for bundling of local and regional usage, but the consumption of local calls does not affect the marginal utility obtained from regional calls and vice-versa. This ensures that the demands for local and regional calls are independent of each other. Second, marginal utility of phone usage (either local or regional) declines with usage. This allows for satiation of demand on flat-rate plans with a zero marginal price since, at some point, the household spends so much time on the phone that it crowds out time spent on outside activities. Third, the utility function allows for the possibility of zero consumption (corner solution) for both goods.

5.2 Estimation Procedure

The predictions from the model consist of an optimal plan choice and a corresponding usage choice for both local and regional service, as a function of the household's observable and unobservable characteristics and the firm/plan's observable and unobservable attributes. We use maximum likelihood methods to estimate the model. The full likelihood is the product of the likelihoods for each household across all markets:

[9] Price endogeneity is potentially not as severe here since the incumbents' prices continue to be actively regulated and the NYPSC requires entrants to file all price changes, thus exerting some lesser degree of regulatory control. We abstract from any remaining unobservable quality differences across plans offered by the same provider. If, for example, AT&T marketed a specific plan to its customers, based on a household characteristic unobserved by the econometrician, and charged a higher price for that plan, the estimated price coefficient would still be biased.

$$\mathcal{L}(\Theta|d,\hat{q}^L,\hat{q}^T,X)=\prod_{h=1}^{H}\prod_{i=1}^{I_h}\mathcal{L}_{ih}(\Theta|d_{ih},\hat{q}^L_{ijh},\hat{q}^T_{ijh},X_{ih}), \tag{10}$$

where the model's parameters are collapsed into the vector Θ and X contains the $I_h \times H$ vectors of household characteristics, D, the $J_h \times H$ vectors of prices, p and P, and the $F_h \times I_h \times H$ vector of firm/household characteristics Z. d is the vector of the household's observed plan choices across plans in its market, and $\hat{q}^L$ and $\hat{q}^T$ denote the household's observed usage.

The log-likelihood function for the household is the log of the joint probability of the household's plan choice, d_{ij}, and its quantity choices, $\hat{q}^L_{ij}$ and $\hat{q}^T_{ij}$. We assume independence between the choice and usage shocks. In our specific application, the choice shock takes the role of unobserved preferences for a specific plan due to, for example, exposure to plan-specific advertising. Correlation between the choice and usage shocks could arise if the provider ran user- and plan-specific advertising campaigns and decided to promote certain plans specifically to households with a particular usage profile. We do not believe such correlations to be very significant in our application. Therefore, the joint probability can be written as the product of the probability that household i chooses plan j conditional on $\hat{q}_{ij}$ and the probability distribution of $\hat{q}_{ij}$. Household i's contribution to the log-likelihood, l_i, equals:

$$l_i(\Theta|d_{ij},\hat{q}^L_{ij},\hat{q}^T_{ij},X_i)=\sum_{j=1}^{J} I_{d_{ij}} \ln\Big\{f(d_{ij}|\hat{q}_{ij},X_i;\Theta)g(\hat{q}_{ij}|X_i;\Theta)\Big\}, \tag{11}$$

suppressing market subscripts for ease of readability. $I_{d_{ij}}$ is an indicator variable set to one if household i chooses plan j and zero otherwise. $f(d_{ij}|\hat{q}_{ij},X_i;\Theta)$ denotes the conditional likelihood of observing household i choosing plan j, while $g(\hat{q}_{ij}|X_i;\Theta)$ denotes the likelihood of observing the usage of $\hat{q}_{ij}$ for local and regional service. For households that consume zero regional calls, Equation (8) implies a value for the regional unobservable, $\hat{\nu}^T_i$, that is the cutoff value for ν where usage is zero.

For any candidate values of the vector of parameters, Θ, the probability that household i chooses plan j is given by the integral over the distribution function of the choice shock:

$$f(d_{ij}|\hat{q}_{ij},X_i;\Theta)=\int_{C_{ij}} dF(\epsilon_i|\nu_i(\hat{q}_{ij})), \tag{12}$$

denoting as $C_{ij}=\{(\nu_i,X_i,\epsilon_{i1},...,\epsilon_{iJ})|v_{ij}\geq v_{ik},\hat{q}_{ij}\in S_{ijk}(\nu_i,X_i,\epsilon_i;\Theta)\ \ \forall k\neq j\}$ the set of individual preferences that lead to choice j. S_{ijk} is the set of feasible quantity choices for household i on plan j with respect to plan k that are consistent with the household choosing plan j over plan k. Such a set can be defined for all possible pairs of plan choices available to the household and potentially places restrictions on the unobserved usage (ν_i) and plan (ϵ_i) preferences that ensure that the observed quantity choices for local and regional usage fall within the feasible set. Thus, there are two conditions which define the individual preferences that lead to the choice of plan j by household i: indirect utility must be maximized on plan j and observed usage must be consistent with indirect utility being maximized on plan j.

To derive the region S_{ijk}, we solve for quantity cutoffs for local and regional usage such that the conditional indirect utility on plan j exceeds that on plan k. These cutoffs are a function of the realized usage preference for the other service ($\nu(\hat{q}^L_{ij})$ for regional usage and $\nu(\hat{q}^T_{ij})$ for local usage), the difference in the unobserved plan preferences for plans j and k, $(\epsilon_{ij} - \epsilon_{ik})$, the prices of plans j and k, and the parameters. Depending on the relative per-call prices on the two plans, the quantity cutoff provides a minimum or maximum observed quantity for which the indirect utility on plan j just equals that on plan k.

Using the constraint that the observed local quantity is consistent with the chosen plan, we can solve for the feasible range of individual preferences, ϵ, that entail household i choosing plan j over plan k and consuming its observed local usage:[10]

$$\begin{aligned}\epsilon_{ij} - \epsilon_{ik} \geq\ & \hat{q}^L_{ij}(p^L_j - p^L_k) + (P^L_j - P^L_k) - (\zeta_{ij} - \zeta_{ik}) - \frac{b_L}{2}[(p^L_j)^2 - (p^L_k)^2] - \\ & \frac{b_T}{2}[(p^T_j)^2 - (p^T_k)^2] + \exp[\alpha^T + \alpha^T_D D_i + \nu(\hat{q}^T_{ij})](p^T_j - p^T_k) + \\ & b^L p^L_j(p^L_j - p^L_k) \equiv \bar{h}^L_{ijk}(\nu(\hat{q}^T_{ij}), X_i; \Theta).\end{aligned} \tag{13}$$

The constraint on the observed regional usage leads to a corresponding expression $\bar{h}^T_{ijk}(\nu(\hat{q}^L_{ij}), X_i; \Theta)$ which can be formed by swapping L and T in the above expression. Appendix 8.2 provides the detailed derivation of Equation (13). Since the constraint on ϵ_i must be met for both local and regional calls, $\epsilon_{ij} - \epsilon_{ik} \geq \max(\bar{h}^L_{ijk}, \bar{h}^T_{ijk})$.

The regions of ϵ_i defined by Equation (13) and the analogous expression for regional calls across all $k \neq j$ define C_{ij}. The fact that the unobserved usage preferences are distributed Type-1 extreme value implies that the difference between any two ϵ_j and ϵ_k follows a truncated logistic distribution with a truncation point of $\max(\bar{h}^L_{ijk}, \bar{h}^T_{ijk})$. We apply a result from Maddala (1983, pages 60 and 61) to derive an analytical expression for the integral in Equation (12). Our assumption that ν_i and ϵ_i are independent simplifies this computation of choice probabilities greatly. The probability that household i chooses plan j, conditional on the realization of the usage preference being consistent with observed usage, is:

[10] Equation (13) abstracts from hybrid plans. We discuss the equivalent expressions in Appendix 8.2.

$$f(d_{ij}|\hat{q}_{ij}, X_i; \Theta) = \frac{1}{\sum_{k=1}^{J} \exp\left[\max\left(\bar{h}^L_{ijk}(\nu(\hat{q}^T_{ij}), X_i; \Theta), \bar{h}^T_{ijk}(\nu(\hat{q}^L_{ij}), X_i; \Theta)\right)\right]}. \tag{14}$$

We now derive the contribution to the likelihood of the households' usage decisions, $g(\hat{q}_{ij}|X_i; \Theta)$, for the subset of households for whom we observe usage. Their chosen usage patterns allow us to identify the variance-covariance matrix of ν_i. In computing $g(\hat{q}_{ij}|X_i; \Theta)$, we account for the fact that our data only provides truncated information on household usage. In particular, we do not observe the local usage of households that choose a flat-rate plan or a hybrid plan if their consumption remains within the plan's allowance. We identify the ranges of ν^L for which our data would not contain the associated usage under our maintained assumption that the chosen plan maximizes households' indirect utility. We then adjust the normal density of ν_i by the probability mass corresponding to the identified ranges in computing the likelihood $g(\hat{q}_{ij}|X_i; \Theta)$.

For each plan in the household's choice set, we identify whether there exists a range of ν^L for which the household's indirect utility in Equations (4) and (5) is maximized. To do so, we determine which plan would be optimal for each possible realization of ν^L by conducting pairwise comparisons of all plans in the choice set. These comparisons rely on differences in ϵ_i that are consistent with the household's chosen plan based on Equation (13) and its counterpart for regional usage. If a particular plan is optimal for a range of ν^L, we then determine whether the plan's type implies that the household's usage would be omitted from our data. We sum the probability masses of the ν^L-ranges associated with plans for which usage would be unreported across all plans in the household's choice set and denote this truncation probability mass by U^L.

Since the comparison of indirect utilities across plans depends on the differences in ϵ_i, we integrate over the distribution of this difference in unobservables using simulation techniques to arrive at a measure of U^L. Figure 3 illustrates the procedure for a household that chooses among a metered plan, a hybrid plan, and a flat-rate plan. Appendix 8.3 provides the detailed steps behind the estimation algorithm, while Appendix 8.4 describes how to simulate from the truncated logistic distribution of the ϵ_i differences.

Formally, the contribution of the household's usage to the likelihood is:

$$g(\hat{q}_{ij}|X_i; \Theta) = \left(\frac{1}{1 - \frac{1}{N}\sum_{n=1}^{N} U_i^{Ln}}\right) \frac{\mathcal{J}_i}{(2\pi)^{\frac{1}{2}}|\Sigma_\nu|^{\frac{1}{2}}} \exp\left\{\frac{-\nu_i(\hat{q}_{ij})'\Sigma_\nu^{-1}\nu_i(\hat{q}_{ij})}{2}\right\} \tag{15}$$

if $\hat{q}^T_{ij} > 0$, and

$$g(\hat{q}_{ij}|X_i; \Theta) = \left(\frac{1}{1 - \frac{1}{N}\sum_{n=1}^{N} U_i^{Ln}}\right) \left(1 - \Phi(\nu_i^T(0))\right) \frac{\mathcal{J}_i}{(2\pi)^{\frac{1}{2}}\sigma_L} \exp\left\{\frac{-(\nu_i^L(\hat{q}^L_{ij}))^2}{2\sigma_L^2}\right\} \tag{16}$$

if $\hat{q}_{ij}^T = 0$. Here, n denotes a draw from the truncated logistic distribution of ϵ_i differences, Φ denotes the normal distribution function of ν^T conditional on ν^L, and $\mathcal{J}_i$ is the Jacobian of the transformation from ν_i to q_{ij}.

When we do not observe the household's local usage, we compute the household's plan-choice probability in Equation (14) based on the regional usage error $\nu(\hat{q}_{ij}^T)$ and by integrating over the unobservable ν_i^L using simulation techniques. Denoting a simulation draw from the empirical distribution of ν_i^L by m, the sample analog of these households' contributions to the log-likelihood is given by:

$$l_i(\Theta|d_{ij}, q_{ij}^L, q_{ij}^T, X_i) \quad = \quad \sum_{j=1}^{J} I_{d_{ij}} \ln \left\{ \frac{1}{M} \sum_{m=1}^{M} f(d_{ij}|q_{ij}^L(\nu_i^{Lm}), \hat{q}_{ij}^T, X_i; \Theta) \right\}.$$

5.3 Identification

Parameters in our model are identified by both the discrete and the continuous choice equations. The parameters of the demand function, a and b, are identified by variation in the observed usage and prices across space and time for households that have chosen a metered plan or consume above the threshold on a hybrid plan. The coefficients on D_i are identified by systematic variation in usage for households with different characteristics, while the covariance parameters in Σ_ν are pinned down by remaining unexplained variance in usage quantities. These allow us to measure how well the observable characteristics explain households' plan choices and consumption. The parameter b is identified by households with similar characteristics facing different per-call prices because they live in different places, consume on different plans, or consume at different times.

The parameters in the perceived firm quality index are identified by variation in household and firm characteristics. The λ parameters are identified by variation in characteristics of each provider's customers, relative to the base category, Verizon households. These different household/firm characteristics lead to different choices of firms' plans by households even at equivalent prices across the firms. The vector of ξ parameters measures the common component of households' preferences in a particular firm/market and is identified by observing multiple households in the same market choosing the same firm.

5.4 Results

In estimation, we allow demand to shift as a function of the household's size, income, age composition, and other communications services used by the household (cellular and Internet service). We also include as a characteristic the plan's coverage area as a measure of the potential population a household can call given its location, as suggested by Taylor and Kridel (1990) and Bodnar et. al. (1988). The chosen utility function does not include income effects for either type of call, which are likely small given the average monthly bill is only 0.74% of the lowest income category. Instead, income is included as a proxy for intensity of use or the opportunity cost of time spent talking on the phone. Finally, we include a fourth quarter dummy to allow for the possibility of increased usage during holiday periods.

To capture differences in households' horizontal preferences for each carrier, we include the household's choice of one of the entrants' long-distance services, whether the household has recently moved into New York State, and the household's monthly income. To limit the number of parameters to be estimated, we assume that customer service and other unobserved quality measures are constant within the metro and non-metro areas and estimate provider-specific fixed effects within these areas. We allow quality differences to vary by market structure by estimating separate fixed effects for the period prior to AT&T's entry in November 1999, for the period of its limited roll-out of service until August 2001, and for the remaining sample period after its entry into all of Verizon's territory. We normalize the parameters that influence the discrete choice by setting the perceived quality of Verizon to zero.

Table 7 contains model estimates. Both local and regional usage are greater if the household owns a cellular phone. This suggests that cellular service proxies for intensity of household communication needs. Internet service is associated with significantly greater demand for local usage, consistent with most households accessing the Internet via phone lines during this time period. Usage of both services is also increasing in household size. The youngest cohort consumes the most of local service, but the least of regional service. Similarly, the middle age bracket consumes more local, but less regional usage than older consumers. Higher income households consume fewer local calls but more regional calls than lower-income households. Households make fewer regional calls during the holiday period but no statistically different use of local calling. Finally, the coverage area of a calling plan has a negative effect on local usage, perhaps due to higher demand for local phone usage in rural areas with smaller coverage areas, but the expected positive effect on regional usage.

The results for the households' discrete choice differ from those obtained when estimating the discrete choice separately, reflecting the effect of the usage decision on the plan choice captured by the full model. The quality dummies for AT&T and MCI are negative, consistent with Verizon's greater market share. Unobserved AT&T quality is greater in non-metro than metro regions, while unobserved MCI quality is greater in the later relative to the earlier period. Households that moved within the last year are more likely to switch to AT&T or MCI, while higher-income households are less likely to switch to AT&T or MCI. Finally, households who have AT&T as their long distance provider are most likely to use AT&T for local service and least likely to subscribe to Verizon. Households who have MCI for their long distance service are most likely to use MCI for their local service, but then prefer Verizon over AT&T, although the latter difference is not significant.

We recognize the nonlinear nature of the pricing plans in calculations of elasticities by estimating both a usage and a choice elasticity shown in Table 7. We compute usage elasticities for both local and regional usage. Relative to previous studies of U.S. telecommunications services (for example, Train, McFadden and Ben-Akiva, 1987; Danaher, 2002), we find a slightly more elastic industry demand for local usage (-2.08), while demand for regional usage is more inelastic (-1.15) than it is for local. Our model allows us to estimate choice elasticities with respect to prices in a way that fully reflects the discrete/continuous nature of the consumers' choices. This is critical for regulators or firms who compute elasticities in markets where firms compete in nonlinear pricing plans. For metered plans, we calculate the percentage response in market share to a percentage change in the fixed fee and local per-call price for each carrier.[11] For both prices, AT&T's residual demand is most elastic. Elasticities for Verizon's metered plans are most inelastic for both the per-call price and the fixed fee. This results from the fact that many households (those located in New York City) do not have a Verizon flat rate plan available as a choice. Therefore, New York City households with a strong preference for Verizon have relatively inelastic demand for the one Verizon product available to them. Similar to the metered plan elasticities, we find an inelastic demand for Verizon's flat-rate plan in response to changes in the fixed fee.

5.5 Consumer Welfare Gains from Entry

Our model allows us to perform various counterfactuals based on the estimated parameters. To assess the welfare implications of restricting the available carriers to Verizon only, we compute the expected consumer surplus that households achieve by choosing the optimal contemporaneous plan available from Verizon and compare it to the expected consumer surplus obtained from choosing the optimal plan under the full range of choices.[12] Estimates of the consumer welfare gains from entry under this counterfactual are displayed in the first row of Table 8. In terms of the compensating variation, we find that across all households, the entry of AT&T and MCI results in monetary savings of approximately \$0.83 or 2.5% of households' average monthly bill. The welfare gains across households vary significantly, however, with a standard deviation of \$3.42 in monetary savings. The large standard deviation results from most households achieving moderate benefits but a few realizing large benefits. We also split up welfare gains by entrant. AT&T households gain more than MCI households, with gains of \$2.77 and \$1.13 per household, respectively.

In addition to having additional choices of carriers, households also experienced

[11] We weigh the choice responses by households' predicted choice probabilities.

[12] We compute the expected consumer surplus using the "log-sum" formula derived in Small and Rosen (1981). We simulate over the unobserved usage preferences holding each household's set of simulation draws fixed (if we do not observe usage) or fixed at the realized unobserved preference (if we observe usage) across all counterfactual analyses.

innovations in pricing plans offered by the entrants. Two important cases of plan introductions are the bundled local and regional service plan offered by AT&T throughout its coverage area and the flat-rate plans introduced by AT&T and MCI in New York City. Verizon in contrast does not introduce new plans in response to competition during the sample period. To quantify the benefits of these plan innovations, we remove these plans from the households' choice sets and compare the expected consumer surplus obtained under this restricted set of options to the baseline. The difference estimates the monetary equivalent of the welfare gain from the introduction of these plans. Row two of Table 8 provides the estimates of the effects from the introduction of AT&T's bundled plan. The average savings from the plan introduction across all households is \$0.21 with a standard deviation of \$1.89. Welfare gains from the other major plan innovation, flat-rate plans in New York City, are listed in the third row of Table 8. Gains from these plans, \$0.68 on average across New York City households, are greater per-capita than from the bundled local and regional calling plan but accrue to only 17.7% of sample households. If averaged across all households the benefits of the New York City flat-rate plans are \$0.12. Both plan introductions thus yield substantial contributions to the overall welfare gain, highlighting the importance of increased product variety as a result of entry.

Our earlier descriptive results pointed to consumers regarding the providers' offerings as differentiated. We estimate the gains from this differentiation by allowing households to choose among the full range of plans, but eliminating any horizontal or vertical quality differences between firms. We do this by equating the non-stochastic portion of the ζ's for the entrants to that of the incumbent (i.e., we set $\zeta_{ij} = 0$ for all plans). Utility differences relative to the baseline expected consumer surplus quantify the differentiation effects from entry. The counterfactual as well as the estimation assumes that Verizon's service quality is constant during the sample period since we have no direct or anecdotal evidence that Verizon significantly improved customer service or increased advertising after entry. The last row of Table 8 summarizes estimates of these effects. We find that on average households gain \$0.26 in monetary savings (0.77% of the average monthly bill) from firm heterogeneity, with a standard deviation of \$1.09. AT&T households benefit most from differentiation (\$1.84 per household on average) relative to MCI households (\$0.64 per household).

We next investigate the extent to which heterogeneity in welfare gains is correlated with household observables. First, we consider welfare gains as a function of the households' valuation of telephone service. We use several observed proxies for valuation of telephone service, including the intensity of usage measured either in terms of calls made or in terms of the predicted local demand intercept, the use of vertical features, and the use of additional communication services, such as Internet, cellular, or paging services. Table 9 displays summary statistics of welfare gains for high and low valuation households. Across all proxies for valuation, high-valuation households realize statistically significant higher welfare gains in monetary terms; however, as a percent of their monthly bill, only usage-intensive households benefit significantly more, both in a statistical and in an economic sense, from entry. New York City households benefit more than other households, however, using the household's predicted local demand intercept as a proxy for usage intensity. As a result, low usage households in New York City benefit by about the same amount as high usage households outside of New York City. In Table 9 we also compare households who benefit from bundling of local and long-distance services (and therefore single-billing) by the entrants to the remaining households. In a confirmation of the descriptive results, we find that gains for households who use an entrant for both services outweigh gains of the remaining households by a factor of five.

The results in Table 10, which explain the monetary welfare benefits by the household characteristics in a Tobit model, reinforce and extend these findings. The welfare gains increase by \$0.22 and \$1.95 for each additional household member for households outside and inside New York City, respectively. Welfare is higher by \$1.20 for black households and decline by a modest \$0.12 for every additional \$1,000 of monthly income. Since larger, lower income households have higher local telecommunications services demand, on average, entry benefits disproportionately high-usage, and thus high-valuation, households. This combined with the results in Table 9 suggests that entry intensified competition for high-valuation customers. As in Table 9, the most significant source of gains is the ability to use a single provider for both services, associated with an increase in welfare gains by \$3.11 and \$1.26 for AT&T and MCI households, respectively.

We conduct several robustness checks to investigate the sensitivity of our results and the accompanying welfare effects to our modeling assumptions. First, we further investigate the importance of inertia, switching costs, and consumer learning about the entrants' services and their own level of demand, which may introduce state-dependence into consumer behavior that we abstract from in our model.[13] We re-estimate the model using data from the second half of the sample period only (Q1 2002 to Q1 2003), a period when consumer learning is arguably likely to have already occurred. The estimated coefficients based on this sub-sample of households imply average welfare effects of \$1.08 per household which is slightly higher, but similar to that of the full sample. Second, as discussed in Section 3, we lose a number of observations due to data incompleteness and data entry errors. The degree of attrition in the data at the carrier level is 15% for AT&T, 38% for MCI, and 24% for Verizon. We re-estimate the model adjusting the likelihood for the differential attrition rates at the carrier level. We find the model estimates to be robust to this alternative likelihood specification.

Lastly, we conduct an additional counterfactual analysis. We investigate the ben-

[13] Narayanan et al. (2007) assess the welfare effects of consumers resolving their demand uncertainty to be modest and primarily generated by uncertainty about their mean usage, as opposed to uncertainty about usage shocks. The households in the setting they study went from mandatory flat-rate service, which provides no financial incentive for consumers to learn their average usage, to having a choice between flat-rate and metered service. In our setting, consumer uncertainty about mean usage is likely to be smaller even prior to entry since consumers either faced a choice of several plans or of only a metered plan, where Narayanan et al. (2007) find uncertainty about mean usage to dissipate very quickly.

efits generated from discounts available to qualifying low-income households. AT&T and MCI offered discounts on the monthly fixed fee for flat-rate plans, while Verizon offered them on flat-rate and metered plans. In our sample, 13.2% of households are billed at the discounted rates. Removing the discounted plans from qualifying households' choice sets suggests that they benefit by on average \$5.18, or 13.2%, from the availability of discounts (averaged over all households the benefits are \$0.69 or 1.75%). These figures represent an upper bound on consumer benefits, however, as our model precludes the households from disconnecting their service altogether in response to an elimination of low-income discounts. We also do not account for the additional waiver of a subscriber line charge in the amount of \$6.50 that the households receive, which increases consumer benefits.

Because our data are of limited duration, we focus on the medium-term effects of unbundling. In the long-term, unbundling may influence the incentives of incumbents and entrants to invest in infrastructure. One of the goals of the 1996 Act is to encourage the rapid deployment of new telecommunications technologies. Whether it provides the correct incentive structure for incumbents and entrants to do so has been debated in the literature (see Hausman and Sidak 2005 for a summary of the issues in question and Crandall, Ingraham, and Singer 2004 for some empirical evidence on the effect of lease rates on incumbents' investment). Avenues for unbundling to contribute to such deployment include providing entrants with an opportunity to invest profits earned through access-based entry to build up over time their own infrastructure and inducing incumbents to increase investments in the more competitive market. At the same time, fear that the new investments would be subject to unbundling might deter such investment. However, such fears have not been realized thus far in the U.S. where no unbundling at cost-based prices has been ordered after the 1996 Act and new fiber-to-the-home networks by AT&T and Verizon are essentially unregulated.

6 Conclusion

A major goal of the 1996 Telecommunications Act was to encourage entry into local phone service with the objectives of achieving better alignment between prices and costs, increased service quality, increased variety of service offerings, and efficiency gains in the form of "one-stop shopping" across different telecommunications services. In this paper, we develop a model to carefully measure the realization of these goals by evaluating consumer welfare gains in each of these areas. We quantify total welfare effects and estimate the contributions from pure price effects, horizontal and vertical quality effects in service provision, and new pricing plan introductions, using a random sample of households in New York State.

Our counterfactual analyses suggest that the average household in the sample benefited by 2.5% of the average monthly bill in total from the additional plan and provider choices introduced by the entrants. Our results show that although households benefit from price reductions due to AT&T and MCI's entry into local phone service, they benefit more from the entrants' plan innovations and quality differences from the incumbent's services. Our work suggests that regulators take into account more than price effects in considering whether to unbundle networks and in evaluating the numerous unbundling experiments taking place around the world. This is of particular relevance for recent years where cellular and Internet phone companies have competed more effectively with local telephone companies for subscribers. By 2007, an estimated 12.8% of households rely solely on cellular phones for communication, while 3.1% use Internet phone service via Voice over Internet Protocol (VOIP). The consumer welfare gains from the increased viability of such services as full substitutes for local phone service likely exceed our estimated welfare gains substantially, both due to increased product variety and increased price competition.

Although unbundling of local service was effectively discontinued in the U.S. in 2004, before its longer-term welfare effects could be evaluated, some of the worldwide examples of unbundling may yield longer time series of data to permit such an evaluation. Interesting extensions to our current results include evaluating whether consumers choose to remain with or continue to switch to entrants' services in the longer-term and whether entrants' service differentiation persists or consumers perceive entrants' services as more homogeneous over time. Other contexts also raise different regulatory issues related to unbundling. For example, under the EU's 2000 Unbundling Regulations, regulators may decide to set lease rates for combined unbundling of voice and data service as well as for limited unbundling of data access only. Our econometric model can easily accommodate consumers' choices to purchase voice and data service from the same or from different firms to estimate the welfare effects of alternative pricing scenarios for full unbundling relative to unbundling of data service only.

7 Bibliography

Berry, S. (1994). "Estimating Discrete Choice Models of Product Differentiation," *RAND Journal of Economics*, 25, 242 – 262.

Berry, S., J. Levinsohn and A. Pakes (1995). "Automobile Prices in Market Equilibrium," *Econometrica*, 64(4), 841 – 890.

________ (2004). "Differentiated Products Demand Systems from a Combination of Micro and Macro Data: The New Vehicle Market," *Journal of Political Economy*, 112(1), 68 – 104.

Bodnar, J., P. Dilworth, and S. Iacono (1988). "Cross-section Analysis of Residential Telephone Subscription in Canada," *Information Economics and Policy*, 3, 311 – 331.

Chan, T. (2006). "Demand for Soft Drinks: Characteristics, Corners, and Continuous Choice," *RAND Journal of Economics*, 37(2), 466 – 482.

Chiang, J. (1991). "A Simultaneous Approach to the Whether, What and How Much to Buy Questions," *Marketing Science*, 10, 297 – 315.

Chiang, J. and L. Lee (1992). "Discrete/Continuous Models of Consumer Demand with Binding Nonnegativity Constraints," *Journal of Econometrics*, 54, 79 – 93.

Crandall, R. W., A. T. Ingraham, and H. J. Singer (2004). "Do Unbundling Policies Discourage CLEC Facilities-Based Investment." *Topics in Economic Analysis & Policy*, 4.

Crandall, R. and J. G. Sidak (2002). "Is Structural Separation of Incumbent Local Exchange Carriers Necessary for Competition?" *Yale Journal on Regulation*, 19(2), 1 – 75.

Danaher, P.J. (2002). "Optimal Pricing of New Subscription Services: Analysis of a Market Experiment," *Marketing Science*, 21(2), 119 – 38.

DellaVigna, S. and U. Malmendier (2006). "Paying Not to Go to the Gym," *American Economic Review*, 96(3), 694 – 719.

Dubé, J. P. (2004). "Multiple Discreteness and Product Differentiation: Demand for Carbonated Soft Drinks," *Marketing Science*, 23(1), 66 – 81.

Dubin, J. (1985). *Consumer Durable Choice and the Demand for Electricity.* Amsterdam: North-Holland.

Dubin, J. and D. McFadden (1984). "An Economic Analysis of Residential Electric Appliance Holdings and Consumption," *Econometrica*, 52, 345 – 362.

Economides, N. (2005). "Telecommunications Regulation: An Introduction," in Richard R. Nelson (ed) *The Limits and Complexity of Organizations.* New York: Russell

Sage Foundation.

Federal Communications Commission (2004). "Local Telephone Competition."

Goolsbee, A. and A. Petrin (2004). "The Consumer Gains from Direct Broadcast Satellites and the Competition with Cable TV," *Econometrica*, 72(2), 351 – 381.

Greenstein, S. and M. Mazzeo (2006). "The Role Of Differentiation Strategy In Local Telecommunication Entry And Market Evolution: 1999-2002," *Journal of Industrial Economics*, 54(3), 323 – 350.

Hanemann, W. M. (1984). "Discrete/Continuous Models of Consumer Demand," *Econometrica*, 52, 541 – 561.

Hausman, J. and G. Sidak (2005). "Did Mandatory Unbundling Achieve its Purpose? Empirical Evidence from Five Countries," *Journal of Competition Law and Economics*, 1(1), 173 – 245.

Hausman, J., T. Tardiff and A. Belinfante (1993). "The Breaking Up of AT&T and Changes in Telecommunications Regulation: What are the Lessons?," *American Economic Review*, 83, 178 – 184.

Hendel, I. (1999). "Estimating Multiple-Discrete Choice Models: An Application to Computerization Returns," *Review of Economic Studies*, 66, 423 – 446.

Hobson, M. and R.H. Spady (1988). "The Demand for Local Telephone Service Under Optional Local Measured Service." *Bellcore Economics Discussion Paper* No. 50.

Kim, J., G. Allenby and P. Rossi (2002). "Modeling Consumer Demand for Variety," *Marketing Science*, 21, 229 – 250.

Kling, J. and S. Van Der Ploeg (1990). "Estimating Local Call Elasticities with a Model of Stochastic Class of Service and Usage Choice," in A. De Fontenay, M. Shugard, and D. Sibley (eds) *Telecommunications Demand Modeling: An Integrated View.* Amsterdam: North-Holland.

Maddala, G. S. (1983). *Limited-Dependent and Qualitative Variables in Econometrics.* Cambridge: Cambridge University Press.

McFadden, D. (1974). "The Measurement of Urban Travel Demand," *Journal of Public Economics*, 3, 303 – 328.

Miravete, E. (2002a). "Choosing the Wrong Calling Plan? Ignorance and Learning," *American Economic Review*, 93, 297 – 310.

________ (2002b). "Estimating Demand for Local Telephone Service with Asymmetric Information and Optional Calling Plans," *The Review of Economic Studies*, 69, 943 – 971.

Narayanan, S., P. Chintagunta and E. Miravete (2007). "The Role of Self Selection and

Usage Uncertainty in the Demand for Local Telephone Service," *Quantitative Marketing and Economics*, 5(1), 1 – 34.

Nevo, A. (2001). "Measuring Market Power in the Ready-to-Eat Cereal Industry," *Econometrica* , 69(2), 307-342.

Small, K. A. and H. S. Rosen (1981). "Applied Welfare Economics with Discrete Choice Models," *Econometrica* , 49(1), 105-130.

Taylor, L.D. and D. Kridel (1990). "Residential Demand for Access to the Telephone Network," in A. De Fontenay, M. Shugard, and D. Sibley (eds) *Telecommunications Demand Modeling: An Integrated View.* Amsterdam: North-Holland.

Telecommunications Reseach & Action Center (2000). "A Study of Telephone Competition in New York," Attachment 501, Verizon Pennsylvania 271 Filing, Declaration of Maura C. Breen.

________ (2001). "Projected Residential Savings in California's Telephone Market."

Train, K., D. McFadden and M. Ben-Akiva (1987). "The Demand for Local Telephone Service: A Fully Discrete Model of Residential Calling Patterns and Service Choices," *RAND Journal of Economics*, 18, 109 – 123.

Zolnierek, J., J. Eisner and E. Burton (2001). "An Empirical Examination of Entry Patterns in Local Telephone Markets." *Journal of Regulatory Economics*, 19 (2), 143 – 59.

Table 1. Descriptive Statistics – Demographic Variables

Variable	Mean	Std. Dev.	Min	Max	Obs	Description
CELLULAR	0.360	0.480	0	1	5496	At least one cellular phone in hh
INTERNET	0.411	0.492	0	1	5524	Internet access at home
HHSIZE	2.083	1.190	1	5	5524	Number of people in hh
INCOME	3.894	3.385	0.425	12.86	5524	Monthly household income (000)
AGE (15 – 34)	0.110	0.313	0	1	5524	Head of hh between 15 and 34 years old
AGE (35 – 54)	0.353	0.478	0	1	5524	Head of hh between 35 and 54 years old
AGE (55+)	0.536	0.499	0	1	5524	Head of hh above 54 years old
BLACK	0.058	0.234	0	1	5524	Head of hh is black
HISPANIC	0.048	0.214	0	1	5524	Head of hh is Hispanic
RACEO	0.049	0.215	0	1	5524	Head of hh is not white or black
MOVED1Y	0.055	0.228	0	1	4556	Hh moved within last year
NYCITY	0.153	0.360	0	1	5524	Hh lives in New York city
SAMLD	0.388	0.487	0	1	5524	Hh has same local and long-distance carrier
AT&T	0.885	0.319	0	1	592	
MCI	0.853	0.355	0	1	218	
VERIZON	0.306	0.461	0	1	3975	
SAMBILL	0.801	0.400	0	1	3825	Hh billed jointly for local and long distance
AT&T	0.970	0.170	0	1	504	
MCI	0.944	0.231	0	1	195	
VERIZON	0.763	0.425	0	1	2541	

Table 2. Household Carrier and Plan Choices, Usage, and Prices Paid

		Mean	Std. Dev.	Min	Max	Obs
Local carrier choices						
	AT&T	0.090	0.286	0	1	7769
	Frontier	0.120	0.325	0	1	7769
	MCI	0.047	0.211	0	1	7769
	Verizon	0.674	0.469	0	1	7769
	Other	0.070	0.256	0	1	7769
Plan choices						
	Flat-rate plan	0.415	0.493	0	1	5524
	Metered plan	0.475	0.499	0	1	5524
	Other plan[1]	0.109	0.312	0	1	5524
Usage of local service (# of calls)						
	Overall	89.867	105.853	1	1299	2928
	Metered plans	89.164	94.855	1	857	2623
	Other plan types	95.908	173.894	1	1299	305
Usage of regional service (# of calls)						
	% of households, usage = 0	0.655	0.475	0	1	5405
	Overall	5.052	15.557	0	257	5405
	Households with usage >0	14.648	23.694	1	257	1864
Local usage prices per call						
	AT&T	0.107	0.015	0.090	0.120	42
	MCI	0.100	0.000	0.100	0.100	48
	Verizon	0.091	0.011	0.084	0.109	2506
Toll usage prices per call						
	AT&T	0.299	0.048	0.270	0.379	469
	MCI	0.677	0.000	0.677	0.677	218
	Verizon	0.351	0.061	0.270	0.429	3981
Monthly fixed fees						
AT&T	Metered plans	8.214	1.503	6.500	9.500	42
	Other plan types	21.757	2.752	15.350	27.950	550
MCI	Metered plans	6.270	0.000	6.270	6.270	48
	Other plan types	18.344	2.688	14.990	21.990	170
Verizon	Metered plans	5.985	2.091	1.000	8.610	2506
	Other plan types	16.362	3.115	7.850	21.520	1475

[1] Other plans include hybrid plans and the bundled local and regional service plan.

Table 3. Monthly Average Savings of Entrants' Customers
N = 592 for AT&T, N = 218 for MCI

Carrier	Category	Charge	Savings over Verizon	Percentage Savings[1]
AT&T	Basic Charges	$23.25	-$0.26	-1.0%
	Add-on Features Charges	3.18	0.53	2.0%
	Buying long distance from AT&T		0.89	3.3%
	Total Savings		1.15	4.3%
	Standard Error, Savings		9.26	
MCI	Basic Charges	$19.65	-$0.61	-2.9%
	Add-on Features Charges	2.00	-0.06	-0.3%
	Buying long distance from MCI		1.07	5.1%
	Total Savings		0.40	1.9%
	Standard Error, Savings		5.51	

[1] As percentage of average total Verizon charges ($26.69 for AT&T analysis, $20.98 for MCI analysis).

Table 4. Overpayments Made by Households

Category	Switching to AT&T[1]	Switching to MCI[1]	Not Switching to AT&T or MCI[2]	Within AT&T[3]	Within Verizon[4]	Within MCI[5]
Frequency	0.44	0.36	0.40	0.12	0.17	0.10
(Std. Err.)	(0.50)	(0.48)	(0.49)	(0.33)	(0.37)	(0.30)
Mean	-0.22	-0.19	-0.14	-0.38	-0.23	-0.32
Std. Dev.	0.44	0.19	0.11	0.30	0.16	0.23
Median	-0.14	-0.10	-0.12	-0.47	-0.22	-0.40
Min	-6.36	-0.90	-0.71	-0.78	-0.71	-0.49
Max	-0.00	-0.01	-0.00	-0.01	-0.00	-0.06
N	592	218	3981	42	1750	32

[1]As fraction of predicted total Verizon charges. [2]As fraction of predicted charges on optimal AT&T or MCI plan. [3]As fraction of predicted charges on optimal AT&T flat rate plan. [4]As fraction of predicted charges on optimal Verizon flat rate plan. [5]As fraction of predicted charges on optimal MCI flat rate plan.

Table 5. Probit Estimates of Mistaken Provider Choice

	Mistaken Provider Choice Y/N					
	AT&T Customers		MCI Customers		Verizon Customers	
Variable	Coeff. (Std. Err.)	Marg. Effect[1]	Coeff. (Std. Err.)	Marg. Effect[1]	Coeff. (Std. Err.)	Marg. Effect[1]
INTERNET	0.1003	0.0394	0.2480	0.0891	0.1124 **	0.0428
	(0.1236)		(0.2406)		(0.0513)	
CELLULAR	-0.0712	-0.0279	-0.0263	-0.0094	0.1406 ***	0.0536
	(0.1218)		(0.2203)		(0.0510)	
HHSIZE	-0.0282	-0.0111	0.3212 ***	0.1153	-0.1067 ***	-0.0405
	(0.0530)		(0.1009)		(0.0209)	
INCOME	-0.0290	-0.0114	-0.0395	-0.0142	0.0599 ***	0.0227
	(0.0191)		(0.0352)		(0.0074)	
AGE (15 – 34)	-0.7495 ***	-0.2601	-0.1768	-0.0614	0.0519	0.0198
	(0.2321)		(0.3606)		(0.0775)	
AGE (35 – 54)	-0.1252	-0.0489	0.1391	0.0504	0.0618	0.0235
	(0.1414)		(0.2241)		(0.0501)	
MOVED1Y	-0.8651 ***	-0.2850	-1.0462 ***	-0.2636	-0.2725 ***	-0.0983
	(0.3580)		(0.6943)		(0.1050)	
BLACK	-0.7006 ***	-0.2460	0.2341	0.0874	0.8210 ***	0.3183
	(0.2176)		(0.3886)		(0.0949)	
HISPANIC	-0.6582 **	-0.2303	-0.4803	-0.1525	0.6743 ***	0.2639
	(0.3449)		(0.5697)		(0.1021)	
RACEO	0.2013	0.0799	0.4570	0.1743	0.2190 **	0.0851
	(0.3455)		(0.4692)		(0.1027)	
SAMLD	-0.6738 ***	-0.2630	1.2367 ***	0.3257		
	(0.2571)		(0.4730)			
(1 - SAMLD)* SAMBILL	-0.4946	-0.1805	1.5151 ***	0.5409	-0.0470	-0.0178
	(0.3426)		(0.6197)		(0.0597)	
N	592		218		3981	
Log-Likelihood	-367.7		-116.3		-2320.9	
p-value	0.0000		0.0006		0.0000	
Likelihood Ratio Index	0.0947		0.1854		0.1325	

A household is classified as having made a mistaken provider choice if it subscribes to a provider whose pricing plans are not the least expensive for the household's ex-post usage. Monthly dummies and a dummy for September and October 2001 included in the estimation. Dummy variables are included to control for missing data for the MOVED1Y, SAMLD and SAMBILL variables.

* Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level. [1]For discrete variables, marginal effects refer to a discrete change from 0 to 1.

Table 6. Multinomial Estimates of Switching to Entrants

	Choice = AT&T		Choice = MCI	
Variable	Coeff. (Std. Err.)	Marginal Effect[1]	Coeff. (Std. Err.)	Marginal Effect[1]
INTERNET	-0.0752	-0.0054	-0.3828	-0.0061
	(0.1340)		(0.2337)	
CELLULAR	0.0939	0.0075	-0.0094	-0.0003
	(0.1282)		(0.2175)	
NYCITY	-0.7183 **	-0.0488	-0.0546	0.0000
	(0.2958)		(0.4627)	
HHSIZE	0.2563 ***	0.0200	0.1834 *	0.0027
	(0.0611)		(0.1064)	
NYCITY*	0.0399	0.0034	-0.1694	-0.0029
HHSIZE	(0.1188)		(0.2163)	
INCOME	-0.0972 ***	-0.0076	-0.0570 *	-0.0008
	(0.0205)		(0.0339)	
AGE (15 – 34)	0.1934	0.0157	0.3036	0.0053
	(0.2248)		(0.3400)	
AGE (35 – 54)	0.0039	0.0004	-0.0897	-0.0015
	(0.1356)		(0.2219)	
MOVED1Y	0.1122	0.0094	-0.0969	-0.0017
	(0.3156)		(0.5539)	
BLACK	0.5090 **	0.0483	-0.0982	-0.0024
	(0.2274)		(0.3970)	
HISPANIC	-0.6294 **	-0.0393	-0.4645	-0.0058
	(0.2923)		(0.5081)	
RACEO	-0.3597	-0.0271	1.1756 ***	0.0348
	(0.3304)		(0.4436)	
ATTLD	3.0470 ***	0.3526	-0.3956	-0.0118
	(0.1507)		(0.4333)	
MCILD	0.0596	-0.0341	4.3002 ***	0.4224
	(0.4139)		(0.2469)	
(1 - SAMLD)*	-1.3762 ***	-0.0742	-1.7875 ***	-0.0173
SAMBILL	(0.2148)		(0.3528)	
N		3164		
Log-Likelihood		-1350.35		
p-value		0.0000		
Likelihood Ratio Index		0.4055		

The analysis is based on those households that live in an area where all three carriers offered service at the time of the household's bill. Monthly dummies and a dummy for September and October 2001 included in the estimation. Dummy variables are included to control for missing data for the MOVED1Y, SAMLD and SAMBILL variables.
* Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level. [1]For discrete variables, marginal effects refer to a discrete change from 0 to 1.

Table 7. Parameter Estimates and Elasticities

Variable	Local Usage Coeff.	Local Usage Std. Err.	Regional Usage Coeff.	Regional Usage Std. Err.
Demand Intercept (a^S)				
CONSTANT(α^S)	4.9146 ***	0.0266	1.3623 ***	0.0866
INCOME ($\alpha^S_{D,1}$)	-0.0243 ***	0.0027	0.0194 ***	0.0071
INTERNET ($\alpha^S_{D,2}$)	0.1600 ***	0.0185	-0.1064 **	0.0504
CELLULAR ($\alpha^S_{D,3}$)	0.0265 **	0.0147	0.3031 ***	0.0499
HHSIZE ($\alpha^S_{D,4}$)	0.1203 ***	0.0098	0.1504 ***	0.0232
AGE (15 – 34) ($\alpha^S_{D,5}$)	0.1604 ***	0.0250	-0.6090 ***	0.0950
AGE (35 – 54) ($\alpha^S_{D,6}$)	0.0704 ***	0.0146	-0.4540 ***	0.0576
4^{th} QUARTER ($\alpha^S_{D,7}$)	0.0042	0.0141	-0.2462 ***	0.0544
COVERAGE($\alpha^S_{D,8}$)	-0.0206 ***	0.0025	0.3494 ***	0.0714
Demand Slope (b^S)	506.8994 ***	16.0700	9.7873 ***	0.7019
Std. Dev. of ν^S, σ^S	0.4725 ***	0.0167	1.2081 ***	0.0312
Correlation, ν^L and ν^T	-0.2213 ***	0.0655		
Average usage price elasticity	-2.08		-1.15	

Variable	Discrete Choice Coeff.	Discrete Choice Std. Err.
Choice = AT&T		
MOVED1Y (λ_{11})	1.2183 ***	0.2996
INCOME (λ_{12})	-0.2154 ***	0.0238
ATTLD (λ_{13})	9.3138 ***	0.2837
MCILD (λ_{14})	-0.0849	0.3121
$\xi_{ATT(1^{st}WAVE/METRO)}$	-11.3126 ***	0.3083
$\xi_{ATT(1^{st}WAVE/NON-METRO)}$	-0.3235	0.2777
$\xi_{ATT(2^{nd}WAVE/METRO)}$	-8.5298 ***	0.3072
$\xi_{ATT(2^{nd}WAVE/NON-METRO)}$	-4.3078 ***	0.2654
Choice = MCI		
MOVED1Y (λ_{21})	0.5976 *	0.4199
INCOME (λ_{22})	-0.1358 ***	0.0217
ATTLD (λ_{23})	1.0200 ***	0.4048
MCILD (λ_{24})	5.2297 ***	0.3691
$\xi_{MCI(PRE/1^{st}WAVE/METRO)}$	-5.6816 ***	0.3218
$\xi_{MCI(PRE/1^{st}WAVE/NON-METRO)}$	-8.9514 ***	0.4038
$\xi_{MCI(2^{nd}WAVE/METRO)}$	-4.5449 ***	0.3469
$\xi_{MCI(2^{nd}WAVE/NON-METRO)}$	-3.9957 ***	0.3842

Choice elasticity with respect to	AT&T	MCI	Verizon
Local usage price, metered plans	-1.8168	-1.6263	-0.7088
Fixed fee, metered plans	-2.5730	-2.2339	-0.6254
Fixed fee, flat-rate plans	-4.2365	-4.9007	-1.9151
Log-likelihood	-34,378.80		

The number of observations are 4,791 for the discrete choice, 2,876 for local usage, and 4,672 for regional usage. Dummy variables are included to control for missing data for the CELLULAR and MOVED1Y variables. Choice elasticity weights households by likelihood of choosing carrier's plan. * Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

Table 8. Monthly Consumer Welfare Gains in Monetary Equivalent Terms ($): Counterfactual Analyses

	Average Welfare Gain in $ and as % of Avg. Bill* (Std. Dev. of Welfare Gain in $)					
	All hhs		AT&T hhs		MCI hhs	
Overall gains from entry	0.828	2.50%	2.774	7.09%	1.129	3.66%
	(3.415)		(4.578)		(1.924)	
Bundled local and regional plan**	0.211	0.64%	0.661	1.69%		
	(1.887)		(2.667)			
New York City flat-rate plans***	0.681	2.05%	2.215	5.66%	0.807	2.61%
	(3.989)		(6.267)		(1.771)	
Service differentiation	0.256	0.77%	1.837	4.69%	0.643	2.08%
	(1.092)		(2.246)		(2.105)	

* Percent welfare gain measured as fraction of average monthly bill in the sample ($33.16 for all households, $39.14 for AT&T households and $30.87 for MCI households). The "All households" category includes households on AT&T, MCI, and Verizon. ** Only applicable to AT&T households. *** For households located in New York City.

Table 9. Stratified: Average Monthly Welfare Gain in $ and as % of Bill

	Low			High			
	Mean (SD)		N	Mean (SD)		N	T-stat[1]
Local usage*	0.293	2.25%	2,419	1.354	6.18%	2,436	-10.962
	(1.543)			(4.503)			
Use of vertical features**	0.571	3.91%	3,021	1.244	4.15%	1,834	-6.696
	(2.592)			(4.413)			
Use of comm. svcs***	0.741	3.03%	656	1.458	4.00%	1,403	-3.560
	(2.512)			(4.866)			
Demand intercept, $E[a_i^L]^\dagger$							
New York City hhs	0.986	4.41%	587	4.136	9.74%	260	-7.923
	(2.976)			(8.540)			
Remaining hhs	0.470	2.88%	1,843	0.687	3.91%	2,165	-2.531
	(2.144)			(3.102)			
Use of carrier across services‡	0.522	2.10%	4,136	2.569	10.53%	719	-15.200
	(3.142)			(4.276)			

[1]T-test statistic for $\mu_{low} - \mu_{high}$. * High local usage denotes households with above-median usage, including flat-rate households. ** High usage of vertical features denotes households with positive vertical features expenditures. *** High usage of communications services denotes households that use at least one of cellular service, Internet, pager, fax, or a pda. † High demand intercept denotes households with an above-median predicted demand intercept. ‡ High use of carrier across services denotes households that also use their local carrier for long-distance service; low use denotes households that do not.

Table 10. Tobit Estimates of Amount of Welfare Gain

	Coefficient	Std. Error
INTERNET	0.4218	0.2982
CELLULAR	0.3499	0.2873
NYCITY	-1.4622 **	0.7005
HHSIZE	0.2212	0.1398
NYHHSIZE	1.7311 ***	0.2801
INCOME	-0.1153 **	0.0454
AGE (15 – 34)	0.8252	0.5059
AGE (35 – 54)	-0.0326	0.3191
MOVED1Y	0.6709	0.7505
DMOVED	-0.1151	0.8138
BLACK	1.2017 **	0.5157
HISPANIC	-0.7172	0.7158
RACEO	0.5678	0.7071
ATTLD	3.1055 ***	0.4402
MCILD	1.2628 **	0.4942
σ	3.7111 ***	0.0931
N	810	
Log-likelihood	-2184.01	
LRI	0.04	
% uncensored observations	0.98	

* significant at 10%; ** significant at 5%; *** significant at 1%.

Figure 1: Incumbent Local Exchange Carriers, New York State

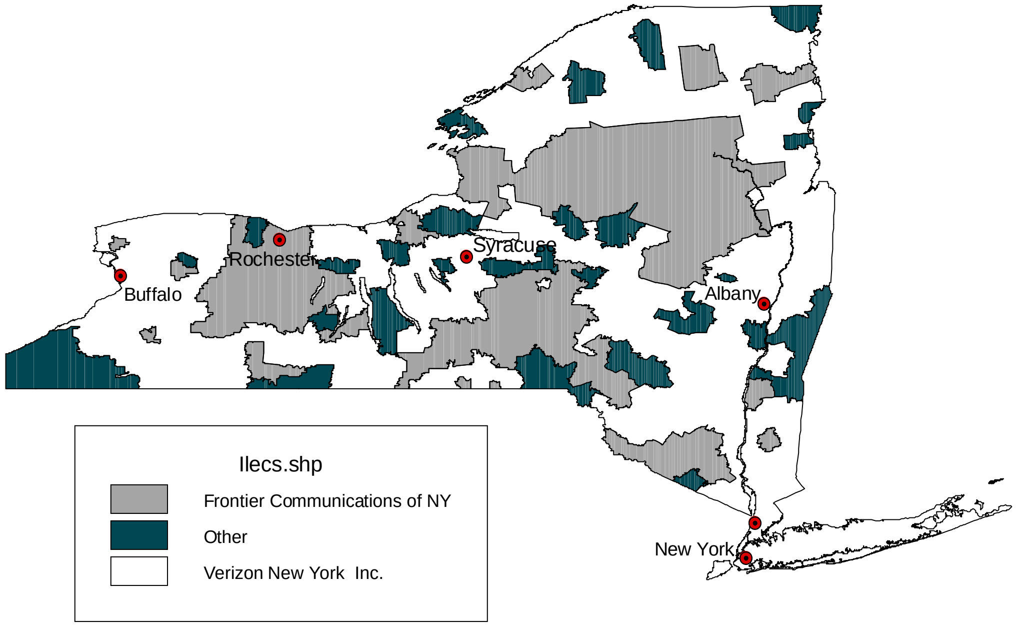


Figure 2: AT&T's Entry into Local Service, New York State, 1999

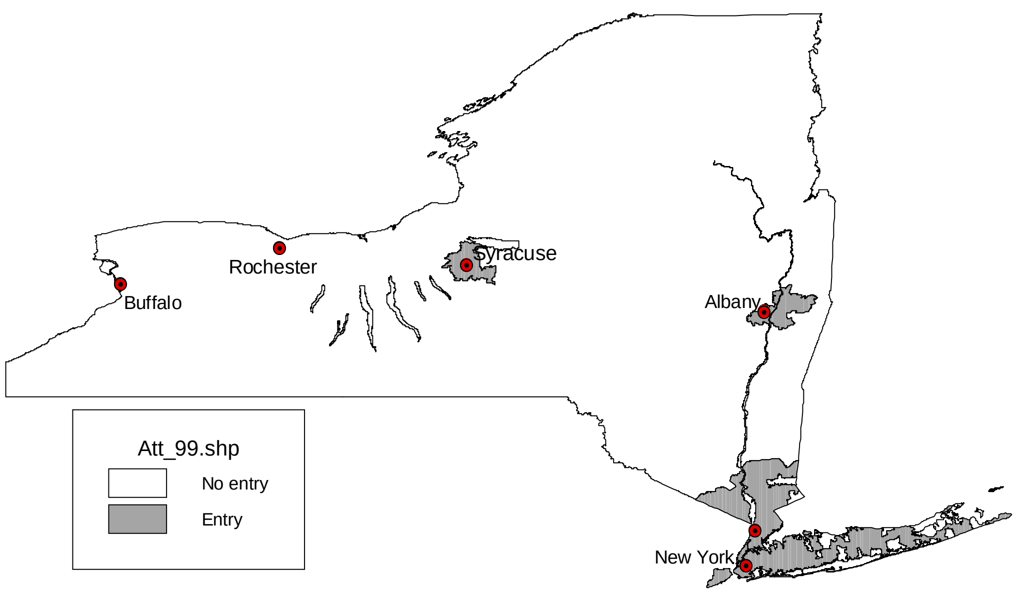
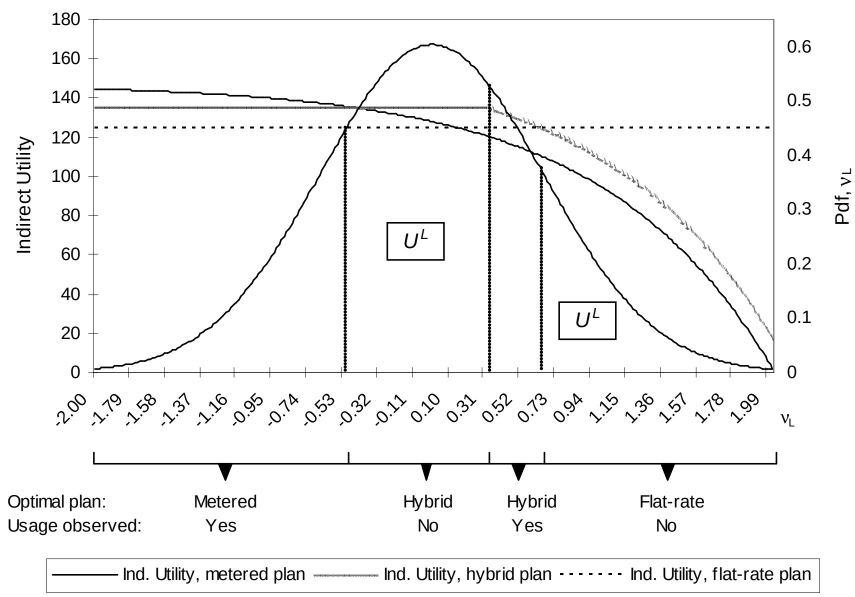


Figure 3: Illustration of Computation of Truncation Mass



8 Appendix

8.1 Estimation of Income

The TNS demographic survey contains a categorical measure of annual household income, placing each household into one of 16 income brackets. To transform these income categories into a single, empirically more convenient measure, we assume that household income is distributed according to a log normal distribution with mean μ and standard deviation σ. The parameters of the distribution are estimated via maximum likelihood, weighting the probability of household income falling into each of the 16 income categories by the frequency with which the category is observed in the data. The continuous income for a household in a particular income category is then derived as the expected conditional value of income for that category based on the estimated log-normal distribution. The resulting income levels are presented in table A1.

Table A1. Parameter Estimates and Conditional Expected Values Empirical Distribution of Household Income

Parameter	Coefficient	Std. Error
μ	10.3712	0.0102
σ	0.9083	0.0083
N	8288	
Log-Likelihood	-22854.72	

Income Category	Frequency	Expected Income
0 – 7,500	511	5,099
7,500 – 9,999	434	8,755
10,000 – 12,499	472	11,239
12,500 – 14,999	382	13,732
15,000 – 19,999	583	17,409
20,000 – 24,999	739	22,401
25,000 – 29,999	595	27,400
30,000 – 34,999	593	32,403
35,000 – 39,999	442	37,406
40,000 – 44,999	423	42,410
45,000 – 49,999	348	47,413
50,000 – 59,999	630	54,673
60,000 – 69,999	400	64,698
70,000 – 74,999	300	72,428
75,000 – 99,999	761	85,887
≥100,000	675	154,315

8.2 Restrictions on Unobserved Preferences

In this appendix we derive the feasible set for local usage for a household who chooses plan j. The derivation of constraints on regional usage is analogous. To derive a constraint on local usage for household i who prefers plan j to plan k, we first find the range of ν_i^L for which plan j is preferred to plan k conditional on the unobserved plan preferences ϵ_{ij} and ϵ_{ik} and the unobserved preference for regional usage ν_i^T. Household i chooses plan j over plan k when the indirect utility from plan j exceeds that from plan k (i.e., $v_{ij} > v_{ik}$). Using the indirect utility function (Equation (4)) conditional on a particular realization of ϵ_{ij}, ϵ_{ik} and ν_i^T, this leads to a cutoff $\bar{\nu}_{ijk}^L(\nu_i^T, X_i, \epsilon_i; \Theta)$ such that:

$$\begin{aligned}
\exp[\nu_i^L] \quad < \quad & \frac{1}{\exp[\alpha^L + \alpha_D^L D_i](p_j^L - p_k^L)} \Big\{ (P_k - P_j) - (\zeta_{ik} - \zeta_{ij}) - (\epsilon_{ik} - \epsilon_{ij}) \\
& - \frac{b^L}{2}[(p_k^L)^2 - (p_j^L)^2] - \frac{b^T}{2}[(p_k^T)^2 - (p_j^T)^2] + \exp[\alpha^T + \alpha_D^T D_i + \nu_i^T](p_k^T - p_j^T) \Big\} \\
& \equiv \exp(\bar{\nu}_{ijk}^L(\nu_i^T, X_i, \epsilon_i; \Theta)),
\end{aligned} \tag{17}$$

if $p_j^L > p_k^L$. If $p_j^L < p_k^L$, then $\exp[\nu_i^L] > \exp(\bar{\nu}_{ijk}^L(\nu_i^T, X_i, \epsilon_i; \Theta))$. The cutoff on unobserved local usage preferences translates into a constraint on the observed usage of $\hat{q}_{ij}^L < \bar{q}_{ijk}^L \equiv \exp[\alpha^L + \alpha_D^L D_i + \bar{\nu}_{ijk}^L(\nu_i^T, X_i, \epsilon_i; \Theta)] - b^L p_j^L$ if $p_j^L > p_k^L$ and $\hat{q}_{ij}^L > \bar{q}_{ijk}^L$ if $p_j^L < p_k^L$.

The set of unobserved plan preferences that ensure that this quantity constraint is satisfied result from substituting $\bar{\nu}_{ijk}^L(\nu_i^T, X_i, \epsilon_i; \Theta)$ from Equation (17) into the quantity constraint and rearranging:

$$\begin{aligned}
\epsilon_{ij} - \epsilon_{ik} \quad > \quad & \hat{q}_{ij}^L(p_j^L - p_k^L) + (P_j^L - P_k^L) - (\zeta_{ij} - \zeta_{ik}) - \frac{b^L}{2}[(p_j^L)^2 - (p_k^L)^2] - \\
& \frac{b^T}{2}[(p_j^T)^2 - (p_k^T)^2] + \exp[\alpha^T + \alpha_D^T D_i + \nu_i^T](p_j^T - p_k^T) + \\
& b^L p_j^L (p_j^L - p_k^L) \equiv \bar{h}_{ijk}^L(\nu_i^T, X_i; \Theta),
\end{aligned} \tag{18}$$

which is Equation (13) in the paper. If plan j is a hybrid plan, we observe usage only for households that exceed the allowance. In this case, Equation (18) becomes:

$$\begin{aligned}
\epsilon_{ij} - \epsilon_{ik} \quad > \quad & \hat{q}_{ij}^L(\tilde{p}_j^L - p_k^L) + (P_j^L - P_k^L) - (\zeta_{ij} - \zeta_{ik}) - \tilde{p}_j^L \tilde{q}_j^L - \frac{b^L}{2}[(\tilde{p}_j^L)^2 - (p_k^L)^2] - \\
& \frac{b^T}{2}[(p_j^T)^2 - (p_k^T)^2] + \exp[\alpha^T + \alpha_D^T D_i + \nu_i^T](p_j^T - p_k^T) + b^L \tilde{p}_j^L (\tilde{p}_j^L - p_k^L).
\end{aligned} \tag{19}$$

If the comparison plan k is a hybrid plan, we use as our cut-off on the unobserved preferences the larger of: 1) the cut-off that results from using the indirect utility on plan k for usage above the allowance, and 2) that from using the indirect utility on plan k for usage below the allowance.

8.3 Estimation Algorithm

The estimation uses the demand model and plan and carrier characteristics to predict each household's optimal plan and quantity choices. Parameters are found by maximizing the likelihood of observing the households' actual plan and quantity choices. The estimation procedure works as follows:

1. For each household with missing local quantity data, draw a vector of M errors from a bivariate Normal distribution, representing ν_i^L and ν_i^T, which are held constant through all iterations of the estimation routine. We set M equal to 30.
2. For each household with quantity data, draw a matrix of N $(J_i - 1)$-dimensional errors from a logistic distribution, where J_i is the number of plans available to household i. These represent ϵ_i-differences between one plan in the choice set and the remaining $(J_i - 1)$ plans, which are sufficient to build the ϵ_i-difference for any two plans in the household's choice set as described in Appendix 8.4. We set N equal to 30 and hold these draws constant for the remainder of the algorithm.
3. Assume starting values for the parameters, Θ^0.
4. To impose the correlation between ν_i^L and ν_i^T multiply the vector of ν_i's by the Cholesky decomposition of Σ_ν.
5. For households with observed local and toll quantity information:
   (a) Compute the predicted demand shocks at the current parameter estimates:
      i. Back out the household's realization of ν_i^L and ν_i^T at the observed quantity choices $\hat{q}_{ij}^L$ and $\hat{q}_{ij}^T$ using Equation (8).
      ii. Determine the household's optimal local and regional quantities on each plan based on $\nu(\hat{q}_{ij}^L)$ and $\nu(\hat{q}_{ij}^T)$:
         A. Optimize within each hybrid plan:
            - Compute the optimal usage on the plan based on Equation (2), using the relevant per-call price for usage above $\tilde{q}_j$.
            - If the optimal quantity is below the threshold, then compute the optimal quantity based on a zero per-unit price (Equation (3)). If the optimal quantity based on a zero per-unit price is above $\tilde{q}_j$, then set usage to $\tilde{q}_j$.
         B. Compute the optimal quantity for all metered and flat-rate plans using (2) and (3), respectively.
   (b) Based on the optimal local and regional quantities, compute the plan-choice probabilities at the current parameter estimates:
      i. Compute the indirect utilities on each plan using the appropriate indirect utility function from Equations (4) and (5), net of the ϵ_i plan-specific preferences.
      ii. Compute $f(d_{ij})$ according to Equation (14) conditional on $\nu(\hat{q}_{ij}^L)$ and $\nu(\hat{q}_{ij}^T)$.
   (c) Determine the optimal plan over the entire support of ν^L. Partition the ν^L-support into R segments such that plan r is optimal over segment r, conditional on the current set of parameters, unobservable plan-specific preferences, and the household's optimal regional usage on plan r (based on $\nu(\hat{q}_{ij}^T)$ implied by the chosen plan j).[14] We denote the segments' end points, as in Appendix 8.2, by $\bar{\nu}_i^1, \bar{\nu}_i^2, \ldots, \bar{\nu}_i^{R+1}$ and compute them as follows:
      i. Truncate each draw of ϵ_i^n to be consistent with Equation (13) as described in Appendix 8.4.
      ii. Given the truncated ϵ_i^n's, eliminate all flat-rate plans except the optimal one based on Equation (5). Also, eliminate any other plans that are dominated by another single plan or combination of plans.
      iii. The initial and final segments in the tails of the distribution are defined over $\nu_i^L \in [\bar{\nu}_i^1, \bar{\nu}_i^2]$ and $\nu_i^L \in [\bar{\nu}_i^R, \bar{\nu}_i^{R+1}]$, where $\bar{\nu}_i^1 = -\infty$ and $\bar{\nu}_i^{R+1} = \infty$. In practice we set $\bar{\nu}_i^1 = -5\sigma^L$ and $\bar{\nu}_i^{R+1} = 5\sigma^L$.
      iv. Identify the plan that provides the highest indirect utility at $\nu_i^L = \bar{\nu}_i^1$:

[14] Such a partition into consecutive ranges is possible since indirect utility declines monotonically in ν_i^L. As a result, for flat-rate and metered plans, there exists at most one ν_i^L where the indirect utilities on any pair of plans are equal. The additional nonlinearity of hybrid plans means that there are at most two cut-offs between a hybrid and a metered plan or two hybrid plans where their indirect utilities are equal.

A. For each plan, compute the optimal quantity given $\bar{\nu}_i^1$ as in step 4(a) and the corresponding indirect utilities from Equations (4) and (5).

B. Find the plan g that provides the maximum indirect utility, index it by $r = 1$, and remove it from the consideration set.

v. Find $\bar{\nu}_i^r$, $r = 2, 3, \ldots$:

A. Compute the ν_i^L for which household i is indifferent between plan g and each of the plans k remaining in the consideration set. For each pair of plans, g and k, this cutoff equals:

$$\begin{aligned} \bar{\nu}_{igk} &= \ln\Bigg[\frac{1}{\exp[\alpha^L + \alpha_D^L D_i](p_g^L - p_k^L)}\Big\{(P_k - P_g) - (\zeta_{ik} - \zeta_{ig}) - (\epsilon_{ik} - \epsilon_{ig}) \\ &\quad -\frac{b^L}{2}[(p_k^L)^2 - (p_g^L)^2] - \frac{b^T}{2}[(p_k^T)^2 - (p_g^T)^2] + \exp[\alpha^T + \alpha_D^T D_i + \nu_i^T](p_k^T - p_g^T)\Big\}\Bigg]. \end{aligned} \tag{20}$$

If plan g is a hybrid plan, we compute two separate cutoffs, one for $p_g^L = 0$ and one for $p_g^L = \tilde{p}_g^L$, as discussed in Appendix 8.2. We then verify that the resulting cutoffs $\bar{\nu}_{igk}(\ p_g^L = 0, p_k^L)$ and $\bar{\nu}_{igk}(\ p_g^L = \tilde{p}_g^L, p_k^L)$ entail usage that falls into the usage segment where the respective usage price applies, with $q_{ig}^L(\bar{\nu}_{igk}(\ p_g^L = 0, p_k^L)) \leq \tilde{q}_g^L$ and $q_{ig}^L(\bar{\nu}_{igk}(\ p_g^L = \tilde{p}_g^L, p_k^L)) > \tilde{q}_g^L$, and retain only those cutoffs that satisfy their quantity restriction. If both plans g and k are hybrid plans, we allow for the possibility of four separate cutoffs and verify quantity conditions on both plans, which again results in at most two cutoffs between the two plans.

B. Cutoff $\bar{\nu}_i^r$ is the minimum $\bar{\nu}_{igk}$ for all k. Denote the associated plan by g and index it by r. If there was at most one valid cut-point greater than the current cut-point between plan g and each of the remaining plans in the consideration set, remove it from the consideration set since plan g will not be optimal for any $\nu_i^L > \bar{\nu}_i^r$. Repeat step A until all remaining plans in the consideration set have been assigned to a segment of ν_i^L.

(d) Compute the probability mass corresponding to those segments among R for which usage data would be unobserved:

i. Determine over what portion of each segment, if any, we would not observe the local quantity:

A. If plan r is a flat-rate plan, we do not observe usage for any $\nu_i^L \in [\bar{\nu}_i^r, \bar{\nu}_i^{r+1}]$.

B. If plan r is a hybrid plan, we do not observe usage for the portion of $\nu_i^L \in [\bar{\nu}_i^r, \bar{\nu}_i^{r+1}]$ that entails usage below the allowance:
Compute the quantity of local calls at $\bar{\nu}_i^{r+1}$ at a usage price of zero:

$$q_{ir}^L(\bar{\nu}_i^{r+1}) = \exp(\alpha^L + \alpha_D^L D_i + \bar{\nu}_i^{r+1}).$$

- If $q_{ir}^L(\bar{\nu}_i^{r+1}) > \tilde{q}_r$, then compute the ν_i^L in segment r where household i first exceeds the call allowance $\tilde{q}_r$ at the positive usage price $\tilde{p}_r^L$ as:

$$\tilde{\nu}_i^{r+1} = \ln(\tilde{q}_r + b^L \tilde{p}_r^L) - \alpha^L - \alpha_D^L D_i.$$

- If $q_{ir}^L(\bar{\nu}_i^{r+1}) \leq \tilde{q}_r$, we do not observe usage for any $\nu_i^L \in [\bar{\nu}_i^r, \bar{\nu}_i^{r+1}]$ and $\tilde{\nu}_i^{r+1} = \bar{\nu}_i^{r+1}$.

ii. Denote by U_i^{Ln} the probability of ν_i^L falling into any of the segments without usage data:

$$U_i^{Ln} = \sum_{r \in R} \left(I_r^F + I_r^H\right)\left(\Phi\left(\frac{I_r^F \bar{\nu}_i^{r+1} + I_r^H \tilde{\nu}_i^{r+1}}{\sigma_L}\right) - \Phi\left(\frac{\bar{\nu}_i^r}{\sigma_L}\right)\right)$$

where I_r^F is a flat-rate plan indicator and I_r^H a hybrid plan indicator.

(e) Repeat steps (c)–(d) for all N truncated ϵ_i-draws.

6. For households without local quantity information:

(a) Determine the household's optimal quantity on each plan for each ν_i^{Lm} draw and the implied $\nu(\hat{q}_{ij}^T)$ as in step 4(a) above.

(b) Based on the optimal quantities, compute the predicted plan-choice probabilities:

i. Compute the indirect utilities on each plan using the appropriate indirect utility function from Equations (4) and (5), net of the ϵ_i plan-specific preferences.

ii. Compute $f(d_{ij})$ according to Equation (14) conditional on the household's current draw ν_i^{Lm}.

(c) Repeat steps (a) and (b) for all M ν-draws.

7. Compute the joint probability of plan and usage choices for each household and each plan:

(a) For households with observed local usage data, this joint probability equals:

$$l_i = \sum_{j=1}^{J} I_{d_{ij}} \ln \left\{ f(d_{ij}|\nu(\hat{q}_{ij}), X_i; \Theta) \left(\frac{1}{1-\frac{1}{N}\sum_{n=1}^{N} U_i^{Ln}} \right) \frac{1}{(2\pi)^{1/2}|\Sigma_\nu|^{\frac{1}{2}}} \mathcal{J}_i \exp\left[\frac{-\nu(\hat{q}_{ij})' \Sigma_\nu^{-1} \nu(\hat{q}_{ij})}{2} \right] \right\}$$

if $\hat{q}_{ij}^T > 0$, or

$$l_i = \sum_{j=1}^{J} I_{d_{ij}} \ln \left\{ f(d_{ij}|\nu(\hat{q}_{ij}), X_i; \Theta) \left(\frac{1}{1-\frac{1}{N}\sum_{n=1}^{N} U_i^{Ln}} \right) \frac{\left(1-\Phi\left(\nu^T(\hat{q}_{ij}^T=0)\right)\right)}{\sqrt{2\pi}\sigma_L} \mathcal{J}_i \exp\left[\frac{-(\nu^L(\hat{q}_{ij}^L))^2}{2\sigma_L^2} \right] \right\}$$

if $\hat{q}_{ij}^T = 0$. Φ is the cdf of ν^T conditional on $\nu^L(\hat{q}_{ij}^L)$.

(b) For households without local usage data, this probability equals their plan choice probability:

$$l_i = \sum_{j=1}^{J} I_{d_{ij}} \ln \left\{ \frac{1}{M} \sum_{m=1}^{M} f\left(d_{ij} | \nu\left(\hat{q}_{ij}^T\right), \nu_i^{Lm}, X_i; \Theta \right) \right\}.$$

8. Update the parameters to maximize the log likelihood function for the entire sample:

$$\ln \mathcal{L}(\Theta|d, \hat{q}^L, \hat{q}^T, X) = \sum_{i=1}^{I} l_i(\Theta|d_i, \hat{q}_i^L, \hat{q}_i^T, X_i).$$

8.4 Drawing from Truncated Logistic Distribution

For each household with quantity data, we need to draw a matrix of N $(J_i - 1)$-dimensional errors from a logistic distribution, where J_i is the number of plans available to household i. These represent the ϵ_i differences between the chosen plan in the choice set and the remaining $(J_i - 1)$ plans. These are sufficient to build the ϵ_i-differences for all other pairs of plans in the household's choice set. It is necessary to draw the differences with respect to the chosen plan in order to impose the constraints on the draws appropriately. The procedure is:

1. Take a draw from the truncated logistic distribution for the difference in household plan unobservables for each plan $k = 1, 2, \ldots, J_i, k \neq j$ with respect to the chosen plan j:

   (a) Since the unobserved household preferences for a particular plan, ϵ_{ik}, are distributed Type-1 extreme value, the difference between any pair of ϵ_i's is distributed logistically. Therefore the cdf of $\epsilon^*_{ijk} = \epsilon_{ij} - \epsilon_{ik}$ is:

   $$F(\epsilon^*_{ijk}) = \frac{\exp(\epsilon^*_{ijk})}{1 + \exp(\epsilon^*_{ijk})} \forall k \neq j.$$

   (b) To ensure that our ϵ_i draws are consistent with household i choosing plan j over plan k, we must impose the constraints specified in Equation (13): $\epsilon^*_{ijk} > \max(\bar{h}^L_{ijk}, \bar{h}^T_{ijk})$. We can specify: $\bar{\mu} = (1 - \mu)F(\max(\bar{h}^L_{ijk}, \bar{h}^T_{ijk})) + \mu F(\infty)$, where μ denotes a uniform random variable. This simplifies to:

   $$\bar{\mu} = \frac{\mu + \exp(\max(\bar{h}^L_{ijk}, \bar{h}^T_{ijk}))}{1 + \exp(\max(\bar{h}^L_{ijk}, \bar{h}^T_{ijk}))}.$$

   (c) For $n = 1, 2, \ldots, N$:

      i. Draw μ from a standard uniform density.

      ii. Calculate $\bar{\mu}$ according to the formula above.

      iii. Set $\epsilon^{*n}_{ijk} = F^{-1}(\bar{\mu}) = \ln(\bar{\mu}) - \ln(1 - \bar{\mu})$.

2. To construct the draws from the truncated logistic distribution for the difference between all other pairs of plans k and l, calculate: $\epsilon^*_{ikl} = \epsilon^*_{ijl} - \epsilon^*_{ijk}, k, l \neq j$. The constraints are all appropriately imposed since pairs of plans that do not involve the chosen plan j are not subject to any additional constraints.