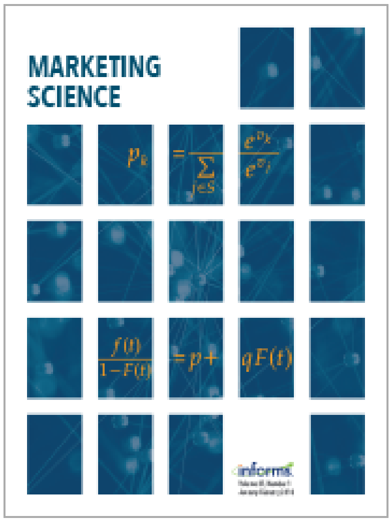

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Does Uncertainty Matter? Consumer Behavior Under Three-Part Tariffs

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In communication, information, and other industries, three-part tariffs are increasingly popular. A three-part tariff is defined by an access price, an allowance, and a marginal price for any usage in excess of the allowance. Empirical nonlinear pricing studies have focused on consumer choice under two-part tariffs. We show that consumer behavior differs under three-part tariffs and assess how consumer demand uncertainty impacts tariff choice. We develop a discrete/continuous model of choice among three-part tariffs and estimate it using consumer-level data on Internet usage. Our model extends prior work in accommodating consumer switching to competitors, thereby capturing behavior in competitive industries more accurately. Our empirical work shows that demand uncertainty is a key driver of choice among three-part tariffs. Consumers' expected bill increases with the variation in their usage, steering them toward tariffs with high allowances. Consequently, demand uncertainty decreases consumer surplus and increases provider revenue. A further analysis of consumers' responsiveness to the different elements of a three-part tariff under the provider's current pricing structure reveals that prices affect a consumer's tariff choice more than her usage quantity and that the allowance plays a strong role in consumer tariff choice. Based on our results, we derive implications for pricing with three-part tariffs.

Key words: pricing; nonlinear pricing; discrete/continuous choice model; Internet access; three-part tariffs; uncertainty; choice
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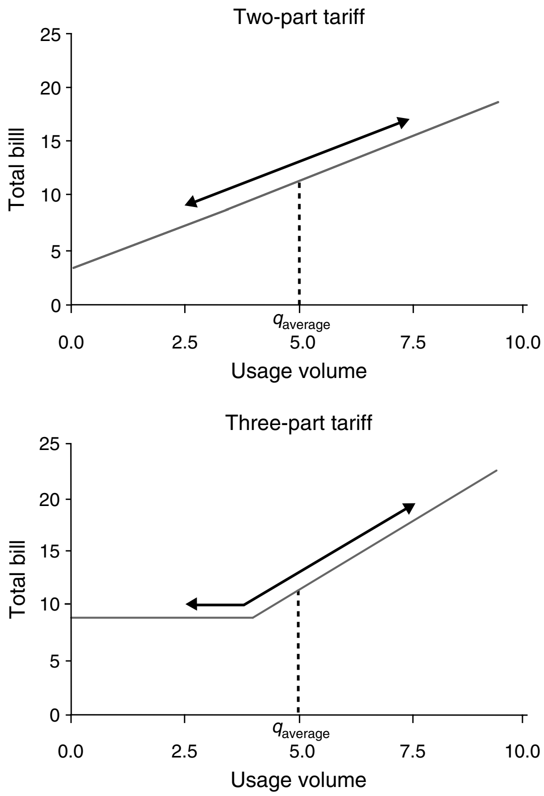
1. Introduction

Across industries, firms in recent years have introduced wide menus of tariffs that grant access to virtually identical products under different pricing structures. For services such as landline telephone and electricity, consumers generally choose between two-part tariffs that differ in their access and usage prices. Three-part tariffs are becoming increasingly popular for communication services (wireless phone service, Internet access) and subscription services (online music download, online newspapers). A three-part tariff is defined by an access price, an allowance, and a marginal price for any usage in excess of the allowance. This paper explores consumer behavior under such three-part tariffs based on an extensive, consumer-level data set on tariff choices and usage from a German Internet service provider.

Despite the prevalence of three-part tariffs in practice, most empirical studies on nonlinear pricing do not research the determinants of consumer choice and demand in such environments (for an exception, see Iyengar 2007). Earlier studies instead focus on two-part tariffs (Danaher 2002, Essegaier et al. 2002, Kling and van der Ploeg 1990, Kumar and Ram 2006, Miravete 2002, Narayanan et al. 2007, Train et al. 1987). A two-part tariff does not include an allowance and the consumer encounters a constant marginal price. In contrast, a three-part tariff implies that the consumer's marginal price on a given tariff depends on her usage: the marginal price is zero if her usage remains within the allowance, but is positive if her usage exceeds the allowance. Accordingly, we expect consumer behavior to be different under two- and three-part tariff pricing.

When consumers sign up for a service, such as wireless phone service, they do not know their exact consumption in minutes in the following billing period. Instead, they commit to a tariff based on their

Figure 1 Effect of Uncertainty Under Two-Part and Three-Part Tariff Pricing



expected usage and their typical month-to-month variation in usage. Consumers only determine their usage of the service over the course of the subsequent billing period based on their chosen plan's prices and allowance. Consumers' uncertainty over future usage in an environment of temporally separated tariff and consumption choices has different implications for their bill under a two- and three-part tariff, as illustrated in Figure 1.

On a two-part tariff, the bill fluctuates with usage volume. The expected bill is unaffected by symmetrically distributed usage variation. Under a three-part tariff, however, usage variation affects the bill asymmetrically because usage fluctuations that remain within the allowance do not alter the bill. As a result, the expected bill likely rises with usage variation. If a provider offers multiple three-part tariffs, the optimal choice for a high variation consumer may be a tariff with a higher access price and allowance than that chosen by a comparable consumer with low-usage variation. Therefore the presence of an allowance uniquely affects the way in which average usage and usage variation determine choice among a menu of tariffs. For the provider, pricing decisions based only on consumers' average usage, ignoring their variation in usage, would be suboptimal. The provider's problem is instead a multidimensional screening problem (Rochet and Stole 2002), where tariff design and pricing exploits two dimensions of consumer heterogeneity: the consumers' average usage and their ability to predict usage. The allowance introduces additional flexibility into the provider's pricing problem to match consumers' tastes along these dimensions, potentially reducing customer attrition and increasing profit.

We develop a model of the consumer's decision process under three-part tariff pricing accounting for the consumer's discrete tariff choice and her continuous usage decision. We relax three assumptions inherent in previous work. First, we account for consumer uncertainty about usage at the time of tariff choice (Narayanan et al. 2007). Our model reflects the separation between plan choice and usage that is typical of communications services pricing. Second, we incorporate tariff-specific preferences that recent research has found to be of importance (Train et al. 1987, Nunes 2000, Lambrecht and Skiera 2006). Third, we model a consumer's decision to switch to another provider, thereby increasing our model's applicability to competitive industries such as Internet access, wireless phone service, or car rental.

The remainder of this paper is organized as follows. We first introduce our data. Next, we develop and estimate a discrete/continuous model of consumer tariff choice and usage under three-part tariff pricing. We then discuss the model results, and conclude with a discussion of the implications of our findings. In our analysis, we make three contributions to the empirical nonlinear pricing literature. (i) We determine the impact of demand uncertainty on consumer choice between three-part tariffs and its effects on consumer surplus and provider revenue. (ii) We estimate elasticities of tariff choice and usage with respect to the access price, the allowance, and the usage price, and thus explore consumers' responsiveness to all elements of a three-part tariff. (iii) We derive implications for pricing from the provider's perspective.

2. Data

Our analysis is based on confidential usage and demographic data from a German digital subscriber line (DSL) Internet access provider for a sample of 11,717 customers with up to five monthly observations from January to June 2003. The data contain demographic information on the user, including gender, age, education, occupation, household size, number of children, and whether or not the user is a business or residential customer. Only 7.6% of users self-identify as business customers.

Internet access is provided on a monthly basis. Customers do not enter into long-term contracts with the provider, so a reassessment of tariff or provider choice

Table 1 Tariff-Switching Matrix

	Switch to … (%)		
	Tariff 1	Tariff 2	Flat rate
Switch from …			
Tariff 1		85.7	14.3
Tariff 2	67.5		32.5
Flat rate	0.0	100.0	

is possible in any given month. The provider offers three tariffs. Tariffs 1 and 2 are three-part tariffs with tariff 2's access price and allowance exceeding those of tariff 1. For usage beyond the allowances, an identical price is charged per megabyte (MB) transmitted, a common pricing structure for providers that offer three-part tariffs. Tariff 3 is a flat-rate tariff with unlimited usage. We cannot tabulate the tariffs' actual prices and allowances because of confidentiality requirements, however, allowances fall between 0 MB and 5,000 MB during the sample period and a typical monthly bill ranges between EURO 4 and EURO 30. Table 1 illustrates consumers' tariff switching behavior within the provider's tariff menu. The majority of switchers move from the original tariff to an adjacent tariff with the next closest allowance and access price.

We also observe consumers leaving the provider. The overall attrition rate is similar to industrywide rates of about 1.8% per month (Gupta et al. 2004). Data on tariff offerings of major competitors during the consumer's billing period show that the competitors' menus of tariffs are limited to at most three tariffs, which we classify into tariffs with a low allowance, tariffs with a medium allowance, and flat-rate tariffs (Table 2). The four major providers held a combined 73% of the German broadband market as of September 2004 (Forrester Research 2005).

Table 3 presents an overview of consumers' usage patterns. The average consumer transmits 2,012 MB per month with a standard deviation of 6,008 MB. Usage varies significantly across demographic groups. Above average users include young consumers (average usage for below 30 year olds of 3,090 MB) and university and other students (average usage of 2,645 MB). Within-consumer usage varies significantly across time as indicated by the standard deviation in

Table 2 Summary of Tariffs across Providers

	Average fixed fee (Euro)	Average allowance (MB)	Average usage price (Euro/MB)
Low allowance	8.90	1,700	0.013
Medium allowance	20.40	6,300	0.013
Flat rate	28.30	Unlimited	–

Total number of tariffs across providers: 10

Table 3 Descriptive Statistics, Monthly Usage

In megabyte	Minimum	Average	Maximum	Standard deviation	Number of observations
Average usage across consumers	0	2,012	121,286	6,008	11,717
Usage across observations	0	1,888	140,394	6,016	49,107
Standard deviation per consumer	0	846	55,398	2,292	11,297*
Coefficient of variation per consumer	0.001	0.495	2.236	0.329	11,297*

*Consumers with only one usage observation excluded.

usage per consumer of on average 846 MB. As Figure 2 illustrates, many consumers use less than the allowance. Among consumers on Tariff 1 (Tariff 2) usage is 50% or less of the respective tariff's allowance for 60.9% (52.8%) of usage observations, whereas only 5.1% (5.0%) of observations exhibit usage of 150% or more of the allowance. Among users 34.0% (42.2%) remain within plus or minus 50% of the allowance. The usage distribution shows a small mass point where usage is approximately equal to the allowance.

Table 4 illustrates the extent to which consumers choose the least costly tariff based on their ex post usage. While Table 4 is based on each consumer's usage during the first available billing period, we obtain very similar results for subsequent billing periods. The rows list the chosen tariff, while the columns list the bill-minimizing tariff for the consumer's realized usage. The diagonal represents consumers who have chosen the tariff that minimizes their bill in that billing period. Across tariffs, between 6.9% and 63.5% of consumer choices do not correspond to the ex post bill-minimizing tariff. The majority of such consumers choose a tariff with an access price above that of the ex post bill-minimizing tariff (lower nonshaded cells), a behavior commonly termed "flat-rate bias" (Train et al. 1987, Nunes 2000, Lambrecht and Skiera 2006). Only a small percentage of consumers (upper nonshaded cells) choose a tariff with an access price that is below the access price of their ex post bill-minimizing tariff.

Because consumers choose a tariff at the beginning of the billing period prior to consumption, the choice is based on the distribution of demand. One explanation for tariff choice biases is that the chosen tariff represents consumers' ex ante optimal choice, with biases reflecting ex post deviations because of demand uncertainty. A multinomial logit model of consumers' tariff choice yields first evidence of the impact of demand uncertainty on tariff choice: controlling for average usage and demographics, the model predicts a significant effect of usage uncertainty on tariff choice: a 1% increase in a consumer's coefficient of variation in usage makes her 3.2% less

Figure 2 **Monthly Usage as Percentage of Allowance, Tariffs 1 and 2**

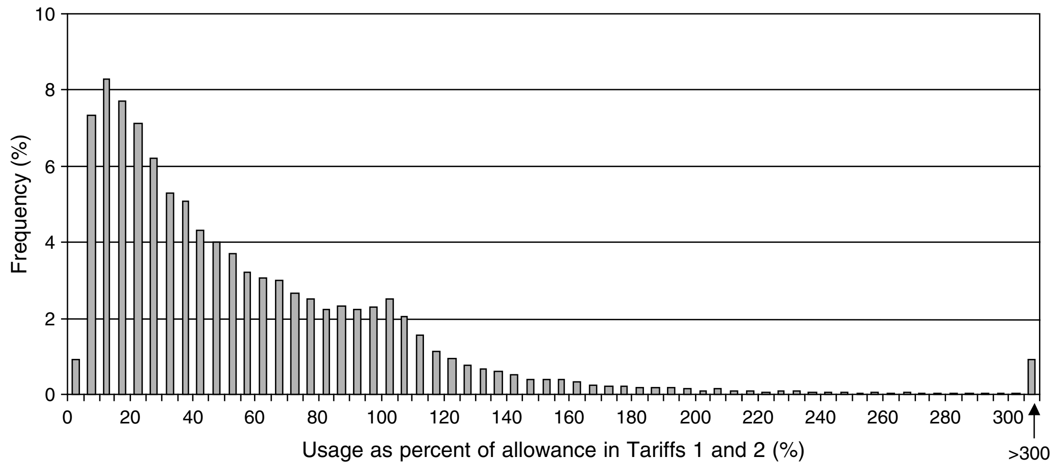


Table 4 **Tariff Choice Biases**

	Best tariff (%)		
	Tariff 1	Tariff 2	Flat rate
Chosen tariff			
Tariff 1	93.1	5.8	1.1
Tariff 2	54.7	36.5	8.8
Flat rate	23.7	9.7	66.6

Note. $N = 11{,}717$.

likely to choose Tariffs 1 over 2. The same change would also make the consumer 0.7% more likely to choose the flat-rate tariff over Tariff 2.

The demand model in §3 incorporates the divergence between ex ante and ex post optimal choices. Earlier studies propose tariff-specific preferences and cognitive mistakes as factors that steer consumers to a tariff with a higher access price and allowance than is optimal ex post. Consumers may prefer a tariff that leads to fewer month-to-month fluctuations in their bill, simplifying budgeting and financial planning, or may derive higher utility from not being charged an additional usage price (Lambrecht and Skiera 2006). We incorporate tariff-specific preferences, but do not further investigate the source of such preferences.

3. Model Development and Estimation

3.1. Model Setup

Our model builds upon Hanemann (1984) who lays out a framework for analyzing demand problems that are mixtures of discrete and continuous choices. Discrete/continuous choice problems have been estimated for various contexts, including the demand for utility services (Dubin and McFadden 1984, Olmstead et al. 2007, Hausman et al. 1993) and for consumer goods (Nair et al. 2005). Similar to Narayanan et al. (2005) and Economides et al. (2006), the availability of detailed, consumer-level usage data allows us to fully estimate the interplay between the discrete tariff and continuous usage decision, in this case in the context of three-part tariff pricing.

We assume that the consumer chooses a tariff among the set offered by her provider and its competitors in each month. The tariff choice is a discrete choice that reflects the distribution of usage for that period. We assume that the cost of switching between tariffs of the same provider is zero because consumers can switch their tariffs online instantaneously. Conditional on the tariff choice, the consumer then makes a continuous usage decision. We consider total transmission volume in MB during the billing period to be the relevant measure of usage. While consumers can adjust usage patterns during the course of a billing period, the data do not show evidence of such intertemporal substitution within a billing period.

3.1.1. Utility Function. The consumer has a choice between a set of J three-part tariffs. Each tariff j is defined by a monthly access price, denoted by F_j, an allowance measured in MB of data transmission, $\tilde{q}_j$, and a marginal price, p_j, charged for each MB of usage that exceeds the tariff's monthly allowance. Within a provider's portfolio, a higher access price is associated with a higher allowance, so that $F_j < F_k$ if $\tilde{q}_j < \tilde{q}_k$. For the tariffs offered by our provider, consumers have a choice between 2 three-part tariffs and one flat-rate tariff, with an unlimited allowance or $\tilde{q} = \infty$, so that $F_1 < F_2 < F_3$ and $\tilde{q}_1 < \tilde{q}_2 < \tilde{q}_3 = \infty$.

We assume that consumer i at time t chooses the optimal tariff j and consumption levels for Internet access, q^*_{ijt}, and the outside good, q^*_{iOt}, to maximize her utility subject to the budget constraint. We assume that utility on tariff j is represented by the following quadratic utility function:

$$U_{ijt}(q_{ijt}, q_{i0t}) = c_i\left[\frac{1}{b}\left(d_{it}q_{ijt} - \frac{(q_{ijt}^2 + d_{it}^2)}{2}\right) + q_{i0t}\right] + \varsigma_{ijt}, \quad b,\, c_i,\, d_{it} > 0, \quad (1)$$

with a budget constraint of

$$y_{it} = q_{i0t} + F_j + (q_{ijt} - \tilde{q}_j)I_{q_{ijt}>\tilde{q}_j}p_j, \quad (2)$$

where the price of the outside good has been normalized to one. The price per unit of Internet usage, p_j, is strictly positive only for $q_{ijt} > \tilde{q}_j$, instances which we capture with the indicator variable $I_{q_{ijt}>\tilde{q}_j}$ set to one if $q_{ijt} > \tilde{q}_j$, and zero otherwise.

Because of the nonlinear budget constraint, we solve the constrained maximization problem separately for the two usage prices. This entails a consumer's optimal demand for usage q_{ijt}^*, conditional on choice of tariff j, of

$$q_{ijt}^* = \begin{cases} d_{it} - bp_j & \text{if } d_{it} - bp_j > \tilde{q}_j \\ d_{it} & \text{if } d_{it} < \tilde{q}_j \\ \tilde{q}_j & \text{if } d_{it} - bp_j \le \tilde{q}_j \le d_{it}. \end{cases} \quad (3)$$

In Equation (3), b represents the demand slope measuring the change in usage per unit change in price, while d_{it} represents baseline demand at a usage price of zero. The first part of Equation (3) accounts for the case when usage exceeds the allowance and a strictly positive usage price applies, the second part for usage below the allowance when p_j equals zero. If optimal usage exceeds the allowance of $\tilde{q}_j$ at a marginal price of zero, but falls short of the allowance at the positive marginal price, we set q_{ijt}^* equal to $\tilde{q}_j$. For this range, the incremental value of usage beyond the allowance is not justified by the additional usage charges that accrue abruptly, resulting in a mass point at the allowance.

Substituting the consumer's optimal demand for the outside good and usage into the utility function yields the conditional indirect utility function

$$U_{ijt}^*(y_{it}, p_j, F_j) = \begin{cases} c_i[y_{it} - F_j] + \varsigma_{ijt} & \text{if } q_{ijt}^* \le \tilde{q}_j \\ c_i\left[y_{it} - F_j + p_j\tilde{q}_j - \left(d_{it} - \frac{bp_j}{2}\right)p_j\right] + \varsigma_{ijt} & \text{if } q_{ijt}^* > \tilde{q}_j. \end{cases} \quad (4)$$

In the indirect utility function, c_i represents the marginal utility of income and ς_{ijt} captures observable and unobservable consumer and plan-specific characteristics of tariff j.

While the demand system implies a simple linear relationship between price and usage regardless of the price level, the quadratic utility function has several advantages compared to alternative specifications. In particular, it allows for satiation. This is necessary to appropriately reflect consumer behavior in our data as many consumers use less than the maximum possible amount of usage at a usage price of zero. In addition, wealth affects in demand, which we cannot estimate because of lack of income information in the data set, drop out of the choice probabilities for a quadratic utility function.

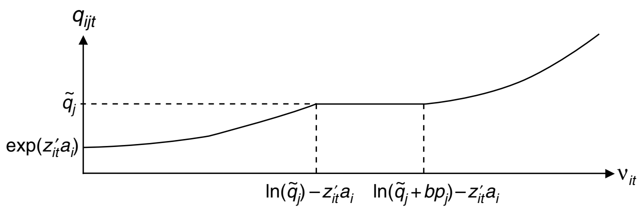
3.1.2. Tariff Choice. A consumer's tariff choice is a function of tariff-specific preferences, ς_{ijt}. We include observable and unobservable preference shifters to account for tariff- and provider-specific preferences identified in previous research (Nunes 2000, Lambrecht and Skiera 2006). We decompose ς_{ijt} into three observed preference shifters and an unobserved preference shifter, ε_{ijt}, that the consumer knows at the time of her tariff choice.

$$\varsigma_{ijt} = \gamma_0 I_j^{FR} + \gamma_1 I_j^{FR} BUS_i + \gamma_2 I_j^P + \varepsilon_{ijt}. \quad (5)$$

We measure a consumer's inherent preference for a flat-rate tariff beyond usage considerations by including the observed preference shifter I_j^{FR} that is one if tariff j is a flat-rate tariff. We allow for differential preference of the flat-rate tariff by business and residential customers by including an interaction between the flat-rate tariff indicator and the business customer indicator, $I_j^{FR}BUS_i$. In addition, we measure a provider preference that reflects perceived quality differences, inertia, or switching costs. We include an indicator, I_j^P, that is one if plan j is offered by one of the competitors. A negative coefficient γ_2 thus represents an inherent preference for the current provider over competitors.

We allow for consumer uncertainty over usage at the time of tariff choice. We incorporate a usage shock, ν_{it}, into consumer demand to reflect random variation in usage, which we assume to be normally distributed with mean zero and standard deviation $\sigma_{\nu i}$. When choosing a tariff, the consumer knows the usage shock only in distribution. Following the tariff choice but prior to making her actual usage decision, she learns about her usage shock. However, the usage shock is unobserved by the researcher throughout. The usage shock ν_{it} shifts the conditional demand function through its affect on the demand intercept, which we specify as $d_{it} = e^{z_{it}'\alpha_i + \nu_{it}}$. z_{it}' denotes a vector of consumer characteristics and time trends that affect demand. We define the demand intercept as an exponential function to ensure a positive demand intercept and substitute it into Equations (3) and (4).

Figure 3 Mapping from Usage Shock to Usage, Three-Part Tariff



For given consumer characteristics, z'_{it}, and prices for a particular tariff, consumption on a three-part tariff depends nonlinearly on the realization of ν_{it}. For values of $\nu_{it} < \ln(\tilde{q}_j) - z'_{it}a_i$, usage is on the flat part of the tariff, below $\tilde{q}_j$, where p_j is by definition zero. For $\nu_{it} > \ln(\tilde{q}_j + bp_j) - z'_{it}a_i$, usage exceeds $\tilde{q}_j$. For a usage shock in the intermediate interval $[\ln(\tilde{q}_j) - z'_{it}a_i, \ln(\tilde{q}_j + bp_j) - z'_{it}a_i]$, optimal usage equals $\tilde{q}_j$, consistent with Equation (3). Figure 3 illustrates this mapping from ν_{it} to q_{ijt}. Similar to the model developed in Reiss and White (2005), our model predicts a mass point in the distribution of usage because of the nonlinear usage price entailed by the three-part tariff structure. The usage mass at $\tilde{q}_j$ depends on the variance of the usage shock. The fact that our data show large variation in individual usage over time (Table 3) and only few consumers who use exactly 100% of their allowance (Figure 2) suggests that the variance in unexpected usage shocks is large.

The consumer chooses the tariff that yields the highest expected utility. Since tariff-specific preferences, ς_{ijt}, are observed by the consumer (but not fully by the researcher), the expectation is taken only with respect to the usage shock, ν_{it}. The expected utility from consuming on a three-part tariff is

$$\begin{aligned}
\mathrm{E}[U^*_{ijt}] &= \Pr(q^*_{ijt} \le \tilde{q}_j)\mathrm{E}[U^*_{ijt} \mid q^*_{ijt} \le \tilde{q}_j] \\
&\quad + \Pr(q^*_{ijt} > \tilde{q}_j)\mathrm{E}[U^*_{ijt} \mid q^*_{ijt} > \tilde{q}_j] \\
&= \Pr(q^*_{ijt} \le \tilde{q}_j)c_i(y_{it} - F_j) + \Pr(q^*_{ijt} > \tilde{q}_j) \\
&\quad \cdot c_i\bigg[y_{it} - F_j + p_j\tilde{q}_j + \frac{1}{2}bp_j^2 \\
&\quad - e^{z'_{it}a_i}\mathrm{E}(e^{\nu_{it}} \mid q^*_{ijt} > \tilde{q}_j)p_j\bigg] + \varsigma_{ijt}. \qquad (6)
\end{aligned}$$

Equation (6) takes into account that if the consumer's ex post usage falls short of $\tilde{q}_j$, she only pays the access price, F_j, and no usage charges, whereas if her usage exceeds $\tilde{q}_j$, she incurs additional charges of p_j for each MB of usage. The expected value of $e^{\nu_{it}}$ given that $q^*_{ijt} > \tilde{q}_j$ is

$$\begin{aligned}
\mathrm{E}[e^{\nu_{it}} \mid q^*_{ijt} > \tilde{q}_j] &= \mathrm{E}[e^{\nu_{it}} \mid e^{z'_{it}a_i + \nu_{it}} - bp_j > \tilde{q}_j] \\
&= \mathrm{E}[e^{\nu_{it}} \mid e^{\nu_{it}} > (\tilde{q}_j + bp_j)e^{-z'_{it}a_i}] \qquad (7)
\end{aligned}$$

and the conditional distribution of

$$(e^{\nu_{it}} \mid e^{\nu_{it}} > (\tilde{q}_j + bp_j)e^{-z'_{it}a_i})$$

follows a left truncated lognormal distribution with an expected value of

$$\begin{aligned}
&\mathrm{E}[e^{\nu_{it}} \mid e^{\nu_{it}} > (\tilde{q}_j + bp_j)e^{-z'_{it}a_i}] \\
&\quad = e^{0.5\sigma^2_{\nu i}} \frac{\Phi(\sigma_{\nu i} - [\ln(\tilde{q}_j + bp_j) - z'_{it}a_i]\sigma^{-1}_{\nu i})}{\Phi(-[\ln(\tilde{q}_j + bp_j) - z'_{it}a_i]\sigma^{-1}_{\nu i})}, \qquad (8)
\end{aligned}$$

where $\Phi(\cdot)$ denotes the standard normal distribution function with probability density $\phi(\cdot)$. The probability that the consumer remains within her monthly allowance is

$$\begin{aligned}
\Pr(q^*_{ijt} \le \tilde{q}_j) &= \Pr[\nu_{it} \le [\ln(\tilde{q}_j + bp_j) - z'_{it}a_i]] \\
&= \Phi([\ln(\tilde{q}_j + bp_j) - z'_{it}a_i]\sigma^{-1}_{\nu i}). \qquad (9)
\end{aligned}$$

Denoting $[\ln(\tilde{q}_j + bp_j) - z'_{it}a_i]\sigma^{-1}_{\nu i}$ by x_{ijt}, the indirect utility of consuming on a three-part tariff is

$$\begin{aligned}
\mathrm{E}[U^*_{ijt}] &= \Phi(x_{ijt})c_i(y_{it} - F_j) + (1 - \Phi(x_{ijt})) \\
&\quad \cdot c_i\bigg[y_{it} - F_j + p_j\tilde{q}_j + \frac{1}{2}bp_j^2 \\
&\quad - e^{0.5\sigma^2_{\nu i}} e^{z'_{it}a_i} \frac{\Phi(\sigma_{\nu i} - x_{ijt})}{\Phi(-x_{ijt})} p_j\bigg] + \varsigma_{ijt} \\
&= \bar{U}^*_{ijt} + \varepsilon_{ijt}. \qquad (10)
\end{aligned}$$

For a flat-rate tariff with a marginal price, p_j, of zero, the expected conditional indirect utility in Equation (10) simplifies to

$$\mathrm{E}[U^*_{ijt}] = c_i(y_{it} - F_j) + \varsigma_{ijt}. \qquad (11)$$

Consumer tariff choice is determined by a comparison of expected indirect utilities across tariffs. Here, the consumer trades off certain benefits in the form of differences between access prices and tariff-specific preferences, ς_{ijt}, and uncertain utility ramifications of usage in excess of the allowance. For the three-part tariffs, the standard deviation in the consumer's usage shock, $\sigma_{\nu i}$, affects the indirect utility both through the likelihood of incurring usage charges and through expected usage in instances where usage exceeds the allowance.

We assume that unobserved tariff-specific preferences $\overrightarrow{\varepsilon_{it}}$ drive tariff choice, but do not affect the distribution of demand. The two sets of unobservable characteristics, $\overrightarrow{\varepsilon_{it}}$ and ν_{it}, are independent. Correlation between unobservable characteristics would arise, for example, if the provider ran user- and plan-specific advertising campaigns and decided to promote a flat-rate plan specifically to those consumers who exhibit large variation in usage. We do not observe plan-specific advertising and know from the provider that user-specific campaigns are not part of its marketing strategy.

We also observe consumers who leave the provider. Previous research often assumes that a consumer who leaves the provider disconnects her service completely (Iyengar 2007) and normalizes the consumer's utility of leaving to zero. While this approach is easy to implement, it hardly reflects consumers' actual Internet access choices. Prior to subscribing to DSL Internet access, consumers had to pay a fixed fee of EURO 100–200 for a modem and installation. Given this up front investment and the revealed preference for higher transmission speed, we expect consumers to switch to a different provider rather than to disconnect or *downgrade* to traditional narrowband Internet access.

Assuming that consumers who leave the provider switch to a competitor, we incorporate consumer attrition by allowing each consumer to choose between the current provider's tariff offering and that of its competitors. The consumer compares the expected indirect utility of choosing any of the competitor's tariffs with the expected indirect utility of remaining on one of the three tariffs offered by the current provider.

In summary, we specify the consumer's initial tariff choice as a function of the distribution of her usage, her tariff-specific preference shifters, and the tariffs' prices and allowances. The consumer chooses the tariff that maximizes her expected indirect utility in Equation (10), where the choice set consists of all currently offered tariffs. Subsequent to tariff choice, the consumer makes a usage choice, where demand follows the expression in Equation (3).

3.2. Model Estimation

Estimation is based on two observed decisions: the consumer's actual tariff choice and her usage decision. We estimate the model parameters by maximizing the joint likelihood of these two observed outcomes. We denote the consumer's observed tariff choice by an indicator, $\hat{I}_{ijt}$, that is one if consumer i chooses tariff j, and zero otherwise, and her observed usage choice by $\hat{q}_{ijt}$. Estimation of the model proceeds via simulated maximum likelihood. The likelihood of the observed behavior of an active consumer is the joint probability of her decision to remain with the provider, her tariff choice conditional on not switching, and her usage, once demand uncertainty is resolved. Because we do not observe consumer behavior subsequent to leaving the provider, we estimate only the likelihood of switching providers for such consumers. This equals the probability that the consumer chooses any one of the competing provider's tariffs, or the sum of the choice probabilities for all competitive tariffs in the consumer's choice set.

Let I_{it}^P and I_{ijt}^T denote indicator variables that are one if consumer i remains with the provider in period t and chooses tariff j in period t, respectively, and let $g(q_{ijt})$ denote the probability density of observing usage of q_{ijt}. Consumer i's contribution to the likelihood, l_{it}, then equals

$$l_{it} = \begin{cases} \prod_{j=1,2,3} (\Pr(I_{it}^P = 1) \Pr(I_{ijt}^T = 1 \mid I_{it}^P = 1) \\ \qquad \cdot g(\hat{q}_{ijt} \mid I_{ijt}^T = 1, I_{it}^P = 1))^{\hat{I}_{ijt}} \\ \quad \text{if } i \text{ chooses provider} \\ \Pr(I_{it}^P = 0) \\ \quad \text{if } i \text{ leaves provider.} \end{cases} \tag{12}$$

The probability that consumer i chooses tariff j in month t is given by the integral of the distribution of plan preferences over the set of $\vec{\varepsilon}_{it}$ such that tariff j provides maximal expected indirect utility. Assuming that tariff-specific preferences $\vec{\varepsilon}_{it}$ come from a type 1 extreme value distribution yields closed-form multinomial logit tariff choice probabilities. The probabilities of remaining with the provider and choosing a particular tariff are then

$$\Pr(I_{it}^P = 1) = \frac{\sum_{m=1,2,3} \exp(\bar{U}_{imt}^*)}{\sum_{n=1,\ldots,J} \exp(\bar{U}_{int}^*)} \quad \text{and}$$
$$\Pr(I_{ijt}^T = 1 \mid I_{it}^P = 1) = \frac{\exp(\bar{U}_{ijt}^*)}{\sum_{m=1,2,3} \exp(\bar{U}_{imt}^*)}, \tag{13}$$

where m is the set of tariffs offered by our provider and n is the full set of available tariffs. The assumption of a normally distributed usage shock ν_{it} leads to a probability density of observing actual usage of $\hat{q}_{ijt}$ of

$$g(\hat{q}_{ijt} \mid I_{ijt}^T = 1, I_{it}^P = 1) = \phi(\hat{\nu}_{it}) J_{it}, \tag{14}$$

denoting as J_{it} the Jacobian of the transformation from $\hat{\nu}_{it}$ to $\hat{q}_{ijt}$. In Equation (14), $\hat{\nu}_{it}$ is the unexplained part of $\hat{q}_{ijt}$ based on the usage prediction in Equation (3), and thus the realization of the usage shock ν_{it}.

We estimate both a cross-sectional specification based on a single observation per consumer and a panel specification with all observations for each consumer. The panel specification allows us to control for unobserved individual-specific demand heterogeneity. If unobserved heterogeneity were of importance, but left unaccounted, the estimated demand uncertainty would potentially be overstated (Guo and Erdem 2006). Unfortunately, our ability to represent the data in a panel specification is limited. Most of the available demand shifters are user-specific demographic attributes and only monthly dummies capture variation over time. As a result, we are able to estimate a random-effects specification of the model, where we identify the distribution of the random effect purely based on its assumed functional form. To do so, we specify $d_{it} = e^{z_{it}'a_i + \eta_i + \nu_{it}}$, where the consumer-specific effect η_i controls for differences in consumers' underlying demand that are constant over time and known to consumers, but not the econometrician.

We specify η_i as an *i.i.d.* normally distributed random effect with mean zero and standard deviation σ_η. We estimate σ_η using simulation techniques to integrate over the distribution of η_i in computing probabilities of exceeding the allowance. The ability to use simulation techniques is an advantage of the random-effects specification because it simplifies estimation of the interdependent discrete tariff and continuous usage choices in the panel. As in the cross-sectional specification, we assume that neither the consumer nor the econometrician observe ν_{it}, the transitive, month-specific component of the usage shock at the time of tariff choice. We estimate its standard deviation, $\sigma_{\nu i}$, which we again interpret as usage uncertainty.

While the closed-form tariff choice probabilities are an advantage of a multinomial logit specification, it restricts substitution patterns between choices. We address this potential limitation in two ways. First, in the cross-sectional estimation, we introduce randomness in the specification of the marginal utility of income, c_i, allowing it to vary by consumer by assuming that mean zero deviations from the average marginal utility of income are distributed Normal with a standard deviation of σ_c. Second, we test the robustness of the reported specification by estimating a multinomial probit model. In unreported results, we find quantitatively similar effects to the ones shown below for a probit model where the value of the outside option is normalized to zero instead of incorporating competitor portfolios.

Systematic variation in consumer characteristics and prices that translate into variation in choice and usage behavior identifies the model's parameters. Given the tariff structure used by the provider, we only observe two levels for the marginal price, a price of zero on the flat-rate tariff and for usage on Tariffs 1 and 2 that is below the allowance $\tilde{q}_j$, and a positive price when usage is greater than the allowance. The usage choices of demographically similar consumers under these two price levels identify the price coefficient, b. Data on consumers' actual usage allow us to estimate the standard deviation of the consumer's usage shock $\sigma_{\nu i}$. Both $\sigma_{\nu i}$ and a_i are specified as linear combinations of customer attributes that enter the indirect utility function additively. $\sigma_{\nu i}$ is identified both through the variation in the usage shocks ν_{it} estimated in the usage Equation (3) and through the consumer's expected indirect utility functions (10) and (11). The inclusion of the usage Equation (3) in the likelihood (12), thus yields a second source of variation in addition to the observed tariff choices, which allows separate identification of both a_i and $\sigma_{\nu i}$. We identify the average marginal utility of income, c, and its standard deviation through variation in access prices across tariffs and the tariff choices of demographically similar consumers.

4. Results and Implications for Pricing

4.1. Model Results

In our cross-sectional estimation, we randomly select one usage observation per consumer resulting in 11,517 observations. For the computationally more intensive panel estimation, we select a random sample of 20% of customers, resulting in 9,971 observations for 2,368 customers with on average 4.2 usage periods. Our data's detailed demographic information allows us to control for observed heterogeneity in consumer demand, while the panel specification controls for any remaining unobserved demand heterogeneity. Table 5 summarizes the results.

The significant positive parameter estimate of the flat-rate dummy confirms that consumers have a preference for the flat-rate tariff over the three-part tariffs. In the cross-sectional results, this preference is significantly stronger for business customers than for residential customers. In addition, the results show a negative value for the average outside provider relative to the consumer's current provider choice, indicating a strong preference for the current provider consistent with the presence of state dependence or switching costs in provider choice.

Based on their tariff choice, consumers choose their usage. We estimate the demand slope b to be 1.903 for the cross section. In an alternative unreported specification, we model b as a random coefficient, but find the standard deviation of its distribution to be insignificant. In the panel, we find the demand slope b to be imprecisely estimated at 0.248. One possible explanation for the difference is that the limited amount of variation in the effectively paid usage price is insufficient to precisely pin down consumers' price responsiveness in addition to the distribution of individual heterogeneity.

In the cross section, we model the marginal utility of income, c_i, as a random coefficient. We estimate its mean value to be 0.544, compared to 0.445 in the panel. Though similar in magnitude, the panel estimate of c is not significant, similar to the demand slope above.

Turning to demographic shifters of demand, we find that Internet usage decreases significantly with age. Our results indicate statistically insignificant differences in Internet usage for different levels of educational attainment, occupation, gender, the number of nonwork days per month and across months. In the panel specification, we find the standard deviation of the random effect σ_η to be 0.020 and not significant. This suggests that consumer-specific and thus

Table 5 Parameter Estimates

	Cross section		Panel	
	Estimate	Std. err.	Estimate	Std. err.
Preferences in tariff choice (s_{ijt})				
Flat-rate preference	2.977	0.313***	2.431	1.241*
Interact. Flat-rate tariff—business	1.833	0.477***	1.071	1.707
Provider preference	−9.948	0.267***	−3.619	1.803**
Marginal utility of income				
c	0.544	0.072***	0.445	0.366
σ_c	1.183	0.331***		
Standard deviation of random effect, σ_η			0.020	0.655
Demand intercept[(1)]				
Constant	2.702	0.129***	2.922	0.400***
Age	−0.015	0.003***	−0.021	0.006***
Household size	0.018	0.012	0.022	0.021
Occupation				
School student	0.010	0.066	0.212	0.128*
University student	0.150	0.089*	0.131	0.135
Educational attainment[(2)]				
Apprenticeship	−0.030	0.039	−0.154	0.169
Bachelor's degree (Fachhochschule)	−0.086	0.057	−0.173	0.173
Master's degree	−0.071	0.046	−0.387	0.162**
Female	−0.016	0.032	−0.206	0.096**
Business	−0.373	0.205*	−0.161	0.125
Nonwork days per month	−0.010	0.003***	0.005	0.020
February	0.006	0.038	−0.269	0.075***
March	0.008	0.029	−0.145	0.058**
April	0.026	0.033	−0.211	0.089**
May	0.034	0.028	−0.137	0.073*
June	0.038	0.044	−0.307	0.130**
Demand slope, b				
b	1.903	0.529***	0.248	0.431
Standard deviation of demand, σ_ν				
Constant	1.306	0.051***	1.033	0.188***
Household size	−0.011	0.007	−0.025	0.014*
Age	0.006	0.001***	0.008	0.004**
Occupation University student	−0.113	0.049**	−0.131	0.080
Occupation School student	−0.036	0.053	−0.086	0.073
Business	0.151	0.106	0.046	0.095
Log likelihood	−50,029.597		−41,222.574	
N	11,517		9,971	

Notes. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.
[(1)]Monthly usage is measured in hundreds of megabytes.
[(2)]We control for missing values by including an indicator variable for households with missing information.

time-invariant unobserved differences in usage are not very important, consistent with our previous finding of high within-consumer usage variation. Because of this result and the lack of time-series variation in the independent variables to estimate a more flexible fixed effects specification, we base the counterfactual analyses in §§4.2 and 4.3 on the cross-sectional results.

We specify the standard deviation of the usage shock, $\sigma_{\nu i}$, as a linear function of consumer characteristics. We allow $\sigma_{\nu i}$ to vary by household size, age, occupation, and a user's residential or business status. Capturing heterogeneity in the extent of consumer usage variation allows us to control for potential heteroskedasticity. The results in both the cross-sectional and the panel estimation are similar in magnitude and significance level, suggesting that our measures of usage uncertainty are robust to alternative specifications. The standard deviation of the usage shock, and thus demand uncertainty, varies significantly across consumers. It amounts to 148.8 MB, or 20.4% of predicted usage, for the average consumer, with a standard deviation of 6.5%. The results confirm our reasoning from §2 that unexpected usage shocks are an important attribute of consumer demand.

The standard deviation falls in household size, suggesting that high and low usage levels of different members of the household average out, increases with age of the account holder and decreases for university students. Hence, consumers are heterogeneous in the amount of demand uncertainty they experience. In the next section, we explore in greater detail how demand uncertainty impacts tariff choice.

4.2. Responsiveness of Consumer Behavior to Tariff Changes

Based on our parameter estimates, we estimate tariff choice and usage elasticities with respect to changes in the access price, allowance, and usage prices by simulating consumer tariff choices and usage, assuming the particular price or allowance is increased by 1%. Table 6 summarizes tariff choice and usage elasticities for the cross-sectional model. We find that the elasticities of tariff choice with respect to the access price amount to −0.84 for Tariff 1, −10.15 for Tariff 2, and −5.01 for Tariff 3. Given the estimated high preference for the chosen provider, consumers respond to a price increase primarily by reoptimizing among the provider's own tariffs. For Tariff 1 users, the next best alternative is likely the intermediary three-part tariff. Because of the low average usage of Tariff 1 subscribers, this switch is only attractive to a small group. In contrast, consumers can respond to an increase in

Table 6 Summary of Price Elasticities

		Tariff			
Elasticity of	With respect to	Tariff 1	Tariff 2	Flat rate	Overall
Tariff choice	Access price	−0.843	−10.150	−5.014	
Tariff choice	Usage price	−2.059	−7.284		
Tariff choice	Allowance	0.745	4.985		
Usage	Usage price				−0.076
Usage	Allowance	0.397	0.281		

Note. $N = 11{,}517$.

the access price of Tariff 2 by either downgrading to Tariff 1 or upgrading to Tariff 3. Flat-rate consumers in turn are most likely to downgrade to Tariff 2. These elasticities compare to estimated tariff choice elasticities in two-part tariff environments that range from −0.46 to −2.19 (Train et al. 1987, Danaher 2002).

Tariff 1's choice elasticity with respect to the usage price is −2.06, similar to recent results by Narayanan et al. (2007) of −1.00 to −1.80. Demand for Tariff 2 is more elastic: a 1% increase in the usage price decreases the tariff choice probability by 7.3%. We also find that usage is relatively inelastic to changes in the usage price, with an average elasticity of −0.08. This is below results of previous research on two-part tariff pricing that has found elasticities in the context of local telephone service ranging between −0.10 and −0.75 (Park et al. 1983, Train et al. 1987, Hobson and Spady 1988, Kridel 1988, Kling and van der Ploeg 1990, Kridel et al. 2002) or as large as −1.70 to −2.50 (Narayanan et al. 2007). The small magnitude of the elasticity potentially reflects the chosen linear demand specification as well as the small amount of variation in the providers' prices, which may limit the reliability of this out-of-sample prediction.

In contrast to the analysis of two-part tariff pricing, we also provide results on tariff choice elasticities with respect to changes in the allowance. We find elasticities of 0.75 for choice of Tariff 1 and 4.99 for choice of Tariff 2. An increase in its allowance makes Tariff 2 more attractive to consumers on both Tariff 1 and the flat-rate tariff, giving rise to the higher elasticity. Increasing the allowance by 100 MB, for example, increases the share of consumers by 3.4% for Tariff 1 and 10.2% for TariffC2.

In addition, we analyze the elasticity of usage with respect to changes in the allowance. We find elasticities of 0.40 for Tariff 1 and 0.28 for Tariff 2. This result is interesting from two perspectives. First, usage is more affected by changes in the allowance than by changes in usage price. Second, changes in the allowance primarily affect tariff choice and less so usage, which is in line with our previous results that the pricing structure of a three-part tariff is particularly relevant in tariff choice, but less so in determining the actual usage volume.

To further illustrate the effect of changes in the three components of a tariff on consumer behavior, we consider the effect of varying different components of the three-part tariffs on various consumer types, holding constant the change in the consumer's bill. First, consider a consumer on Tariff 2 whose usage is at 1,000 MB above the allowance. For this consumer, a 1% increase in Tariff 2's access price and a 1% increase in the usage price have the same effect on her bill. However, the increase in the access price decreases the predicted probability of choosing Tariff 2 by 10.2%, whereas the increase in usage price decreases it only by 7.3%. Next, consider a low usage Tariff 1 consumer whose usage exceeds the allowance by 1,000 MB. Decreasing Tariff 1's access price by 3.5% and increasing its allowance by 1% entail identical effects on her bill. Lowering the access price, however, increases the probability of choosing Tariff 1 by 3.0%, whereas increasing the allowance increases the probability of choosing Tariff 1 only by 0.7%.

While our results are contingent on the provider's chosen prices, our analysis of tariff choice and usage elasticities with respect to the components of a three-part tariff also provides more general insights on consumer behavior under three-part tariffs. Previous research has found that tariff choice and usage under a two-part tariff are driven by both access and usage prices. We find in contrast that the pricing elements of a three-part tariff affect primarily tariff choice and less so usage. One reason for this result may be that under a three-part tariff, the average user assesses the probability of exceeding the allowance to be small. We also find that, in addition to the access and usage price, the allowance strongly drives tariff choice.

4.3. Implications of Uncertainty for Consumer Tariff Choice and Surplus and Provider Revenue

In this section, we analyze the impact of demand uncertainty on consumer choice between three-part tariffs. We highlight the revenue implications of such choices, which point to a role for three-part tariffs to more fully exploit demand uncertainty from the provider's perspective than two-part tariffs. We thus provide one explanation for the increasing prevalence of three-part tariffs in many information industries.

Our model estimation shows that unexplained usage variation is large, with a mean of 20.4% of predicted usage. We assess the impact of such variation on the consumer's tariff choice using tariff choice elasticities with respect to changes in the standard deviation of the usage shock, $\sigma_{\nu i}$. We simulate consumer tariff choice by increasing each consumer's demand uncertainty by 1%. Simulations result in elasticities of −3.618% for Tariff 1, −0.146% for Tariff 2, and 3.643% for Tariff 3. These elasticities represent the net effect of consumers switching from Tariff 1 to 2 and the flat-rate tariff and from Tariff 2 to the flat-rate tariff in response to higher usage variation. Our numerical results are thus in line with the expectation that a higher usage shock variance, $\sigma_{\nu i}$, increases the likelihood of choosing a tariff with a higher allowance.

Because of the exponential specification of the usage shock ν_{it}, an increase in its standard deviation increases the expected value as well as the standard deviation of usage, both of which affect tariff

Table 7 Summary of Uncertainty Elasticities

		Tariff		
Elasticity of	With respect to	Tariff 1	Tariff 2	Flat rate
Tariff choice	Std. dev. of usage shock, $\sigma_{\nu i}$	−3.618	−0.146	3.643
Tariff choice	Std. dev. of usage, σ_q	−0.789	−0.069	0.838

Note. $N = 11{,}517$.

choice. To focus exclusively on the role of demand uncertainty, we compute tariff choice elasticities with respect to changes in the standard deviation of usage, holding expected usage on a given tariff constant. We rewrite the demand function as

$$q^*_{ijt} = (1+\alpha)[e^{z'_{it}a_i}e^{\nu_{it}} - bp_j] - \alpha \mathrm{E}(q^*_{ijt}), \quad \text{with}$$
$$\mathrm{E}(q^*_{ijt}) = e^{z'_{it}a_i}e^{0.5\sigma^2_{\nu i}} - (1-\Phi(x_{ijt}))bp_j. \tag{15}$$

In this expression, α measures the percent change in the standard deviation of usage. By including the term $-\alpha\mathrm{E}(q^*_{ijt})$, we hold expected usage constant for increases or decreases in the standard deviation of usage, σ_q. The results in Table 7 confirm that even with a constant expected usage, consumers are more likely to choose a tariff with a higher allowance as demand uncertainty increases. We find an elasticity of −0.789 for Tariff 1 and of −0.069 for Tariff 2, again balanced by a positive elasticity of 0.838 for the flat-rate tariff. This is consistent with our previous finding that consumers are more likely to switch to a tariff with a higher allowance and access price and ultimately to a flat-rate tariff when uncertainty increases. The fact that the elasticities with respect to $\sigma_{\nu i}$ are higher in magnitude than the elasticities with respect to σ_q illustrates that increases in expected usage also shift consumers to tariffs with higher allowances.

Figure 4 illustrates the effect of an increase in σ_q on a consumer's expected bill on the three-part tariffs. For example, an increase in the standard deviation of usage by 20% increases the expected bill on Tariff 1 by 13% on average. This results from changes in expected usage conditional on exceeding the allowance and changes in the probability of exceeding the allowance.

Figure 4 Effect of Changes in σ_q on Average Expected Bill on Tariffs 1 and 2

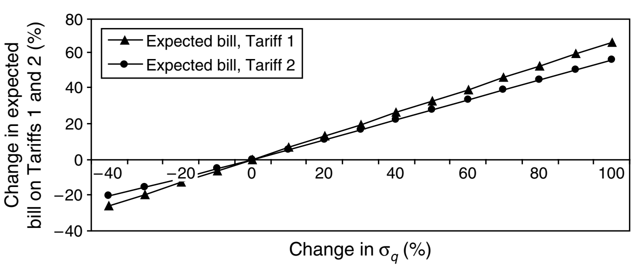
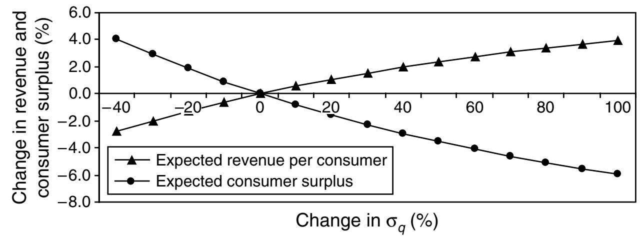


Figure 5 Effect of Changes in σ_q on Provider Revenue and Consumer Surplus



For usage below the allowance, the bill remains constant at the access price, leading to an asymmetric effect of usage variation on the billed amount.

An increase in usage variation, σ_q, thus increases both the probability of choosing a tariff with a higher allowance and the expected bill on a given three-part tariff. This in turn affects provider profit and consumer surplus. For lack of detailed information on the provider's cost structure, we focus instead on revenue implications. Figure 5 illustrates the relationship between changes in σ_q and provider revenue and consumer surplus. We compute expected consumer surplus and provider revenue based on Equation (10) by numerically integrating over the distribution of the unobserved usage and choice shocks.

We find significant changes in consumer surplus and revenue as usage variation increases. For example, when usage variation increases by 20%, consumer surplus decreases by 1.5% and revenue increases by 1.1%. Consumer surplus reflects the changes in the expected bill and decreases steadily with increases in σ_q. Provider revenue, on the other hand, increases in σ_q. Even though the magnitude of the effects may appear small, a windfall revenue gain of 1.1% translating into a similar or larger profit increase is significant from a provider's perspective. The magnitude of the changes also reflects the provider's chosen tariff structure that awards a high allowance to consumers on the smallest tariff, relative to their average usage. An alternative tariff structure that uses the allowance more effectively as a means of price discrimination would entail more significant effects on consumer surplus and revenue.

Our results have several implications for provider pricing. If consumers have uncertainty over their demand, providers can derive revenues under three-part tariff pricing that they cannot derive under two-part tariff pricing. Our results provide some evidence that in environments where choice and consumption are temporally separated, as is the case for many subscription services, three-part tariff pricing may be superior to two-part tariff pricing. In addition, providers have an incentive to target consumers with characteristics that are correlated with high-usage fluctuations to increase revenue. This underlines the importance of considering uncertainty in provider decision making, which is in line with results of other studies in different contexts (Hitsch 2006, Kim et al. 2004, Crawford and Shum 2005).

5. Conclusion

Because of heterogeneous customer demand that is difficult to forecast for each individual customer, firms in service industries frequently segment their customers, so that different customer groups realize different prices. Differentiating prices according to the quantity that is being consumed is particularly attractive in telecommunication industries where the scope for differentiating the service offering is limited. In the past, firms mainly offered two-part tariffs that charge a fixed access price and a marginal usage price. At the extreme, the marginal usage price is zero, resulting in a flat-rate tariff. More recently, firms have introduced a greater variety of pricing schemes. In particular, consumers now frequently choose between multiple three-part tariffs under which a consumer pays an access price for a usage allowance and is charged a positive marginal price only for usage in excess of the allowance. From a provider's perspective, optimally setting prices and allowances of three-part tariffs critically hinges on understanding consumer tariff choice and demand. Consumer behavior under three-part tariffs has, however, largely been unexplored to date.

This paper contributes to closing this gap in the literature. Our findings reveal that changes in the access and usage price affect the consumer's tariff choice more than her usage quantity, and that the allowance plays a strong role in consumers' tariff choice. We also find that consumers have a preference for flat-rate tariffs.

Our results show that consumers have significant uncertainty over their demand and that the extent of such demand uncertainty is heterogeneous. Demand uncertainty is a key driver of choice between three-part tariffs through its positive relationship to the consumer's expected bill. Counterfactual analyses suggest that consumers with high demand uncertainty are more likely to upgrade to a tariff with a higher access price and allowance. Consequently, demand uncertainty decreases consumer surplus and is costly to the consumer. At the same time, providers derive increased revenues from consumers' demand uncertainty. This suggests that it may be beneficial for providers to account for heterogeneity in consumers' usage variation in their marketing strategy, e.g., by specifically marketing to consumers who are likely to exhibit greater demand uncertainty.

Our results also show that three-part tariffs enable providers to segment consumers by both their average usage and fluctuations in their usage. The additional pricing element introduced by the allowance increases the provider's ability to segment customers relative to more traditional menus of two-part tariffs that segment consumers exclusively along their average usage. Our results suggest that firms may benefit from offering three-part tariffs instead of two-part tariffs in settings where consumers commit to a pricing scheme for the quantity they purchase, but only later decide on the number of units per period to purchase, an amount that might differ from their expected usage when choosing their tariff. Such temporal separation of consumer choice and usage occurs in fixed-line and wireless telecommunications, as well as Internet access. Potential other industries include online communities such as social networking sites, financial service companies, including credit card companies, brokerage houses and banks or broadly transportation industries such as airlines, car rental and leasing companies and railways.

While providers benefit from greater demand uncertainty, demand uncertainty increases a consumer's bill and decreases consumer surplus. Consequently, consumers would benefit from pricing schemes that moderate the negative impact of demand uncertainty. One such pricing mechanism is *rollover* pricing where a provider allows a consumer to carry over the unused portions of the usage allowance into the next billing period. In such a setting, a consumer's accumulated usage allowance mitigates the effect of occasional, large usage levels, and we would expect rollover to offset the negative impact of demand uncertainty for the consumer at least partially. This effect might make a provider's offering more attractive in a competitive setting.

Our results also motivate a more extensive study of optimal mechanism design in the context of nonlinear pricing menus with separate choice and usage occasions. An interesting avenue for future research is to determine the optimal number of tariffs and the optimal intervals between different tariffs' access price and allowance combinations.

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References

Crawford, G., M. Shum. 2005. Uncertainty and learning in pharmaceutical demand. *Econometrica* **73**(4) 1137–1173.

Danaher, P. J. 2002. Optimal pricing of new subscription services: Analysis of a market experiment. *Marketing Sci.* **21**(2) 119–138.

Dubin, J., D. McFadden. 1984. An econometric analysis of residential electric appliance holdings and consumption. *Econometrica* **52**(2) 345–362.

Economides, N., K. Seim, V. B. Viard. 2006. Quantifying the benefits of entry into local phone service. Working paper, Stanford Graduate School of Business, Stanford, CA.

Essegaier, S., S. Gupta, Z. J. Zhang. 2002. Pricing access services. *Marketing Sci.* **21**(2) 139–159.

Forrester Research. 2005. German broadband: Slow progress.

Guo, L., T. Erdem. 2006. Measuring usage flexibility in wireless tariff choice. Working paper, Hong Kong University of Science and Technology, Hong Kong, China.

Gupta, S., D. R. Lehman, J. A. Stuart. 2004. Valuing customers. *J. Marketing Res.* **41**(1) 7–18.

Hanemann, W. M. 1984. Discrete/Continuous models of consumer demand. *Econometrica* **52**(3) 541–561.

Hausman, J., T. Tardiff, A. Belinfante. 1993. The effects of the breakup of AT&T on telephone penetration in the United States. *Amer. Econom. Rev.* **83**(2) 178–184.

Hitsch, G. 2006. An empirical model of optimal dynamic product launch and exit under demand uncertainty. *Marketing Sci.* **25**(1) 25–50.

Hobson, M., R. H. Spady. 1988. The demand for local telephone service under optional local measured service. Bellcore Economics Discussion Paper 50, Morristown, NJ.

Iyengar, R., A. Ansaro, S. Gupta. 2007. A model of consumer learning for service quality. *J. Marketing Res.* Forthcoming.

Kim, B.-D., M. Shi, K. Srinivasan. 2004. Managing capacity through reward programs. *Management Sci.* **50**(4) 503–520.

Kling, J. P., S. S. van der Ploeg. 1990. Estimating local call elasticities with a model of stochastic class of service and usage choice. A. de Fontenay, M. H. Shugard, D. S. Sibley, eds. *Telecommunications Demand Modelling. An Integrated View*. North-Holland, Amsterdam, The Netherlands, 119–136.

Kridel, D. J. 1988. A consumer surplus approach to predicting extended area service (EAS) development and stimulation rates. *Inform. Econom. Policy* **3**(4) 379–390.

Kridel, D., P. Rappoport, L. Taylor. 2002. IntraLATA long-distance demand: Carrier choice, usage demand and price elasticities. *Internat. J. Forecasting* **18**(4) 545–559.

Kumar, N., R. Ram. 2006. Using basket composition data for intelligent supermarket pricing. *Marketing Sci.* **25**(2) 188–199.

Lambrecht, A., B. Skiera. 2006. Paying too much and being happy about it: Existence, causes and consequences of tariff-choice biases. *J. Marketing Res.* **43**(2) 212–223.

Miravete, E. J. 2002. Estimating demand for local telephone service with asymmetric information and optional calling plans. *Rev. Econom. Stud.* **69**(4) 943–971.

Nair, H., J.-P. Dubé, P. K. Chintagunta. 2005. Accounting for primary and secondary demand effects with aggregate data. *Marketing Sci.* **24**(3) 444–460.

Narayanan, S., P. K. Chintagunta, E. J. Miravete. 2007. The role of self-selection and usage uncertainty in the demand for local telephone service. *Quant. Marketing Econom.* **5** 1–34.

Nunes, J. 2000. A cognitive model of people's usage estimations. *J. Marketing Res.* **37**(November) 397–409.

Olmstead, S. M., W. M. Hanemann, R. N. Stavins. 2007. Water demand under alternative price structures. *J. Environ. Econom. Management* **54**(2) 181–198.

Park, R. E., B. M. Wetzel, B. M. Mitchell. 1983. Price elasticities for local telephone calls. *Econometrica* **51**(6) 1699–1730.

Reiss, P. C., M. W. White. 2005. Household electricity demand, revisited. *Rev. Econom. Stud.* **72**(3) 853–883.

Rochet, J.-C., L. A. Stole. 2002. Nonlinear pricing with random participation. *Rev. Econom. Stud.* **69** 277–311.

Train, K. E., D. L. McFadden, M. Ben-Akiva. 1987. The demand for local telephone service: A fully discrete model of residential calling patterns and service choices. *Rand J. Econom.* **18**(1) 109–123.