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Abstract

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.

Keywords

pricing, nonlinear pricing, discrete/continuous choice model, Internet access, three-part tariffs, uncertainty, choice

Disciplines

Business | Economics | Management Sciences and Quantitative Methods

Does Uncertainty Matter?
Consumer Behavior under Three-Part Tariffs

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Abstract

In communication, information, and other industries, three-part tariffs are becoming increasingly popular. A three-part tariff is defined by an access price, a usage allowance, and a marginal price for any usage in excess of the allowance. The nonlinear-pricing literature has focused primarily on two-part tariffs. We show that consumer behavior differs under three-part tariffs, in particular regarding the impact of consumers' usage uncertainty on tariff choice. We develop a discrete/continuous model of tariff choice among three-part tariffs and estimate the model using consumer-level data on Internet usage. By allowing consumers to switch from their current provider to a competitor, we model behavior in competitive industries. Our results show that demand uncertainty is a key driver of choice between three-part tariffs. For a given tariff and average usage, the expected bill increases with the variation in consumer demand, steering consumers towards tariffs with high usage allowances. Consequently, demand uncertainty decreases consumer surplus and increases provider revenue. In addition, we analyze consumers' responsiveness to the different elements of a three-part tariff. We find that the access price is the main driver of consumer tariff choice, whose effects dominate any sensitivity to the usage price or the allowance. Based on our results we derive implications for pricing with three-part tariffs.

Keywords: Nonlinear Pricing, Discrete/Continuous Choice Model, Internet Access, Three-Part Tariffs, Uncertainty.

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1 Introduction

In recent years, firms in a number of industries have introduced wide menus of pricing plans that grant access to virtually identical products under different pricing schemes. 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, however, becoming increasingly popular for communication services (wireless phone service, Internet access), subscription services (online music download, online newspapers), or car rental. A three-part tariff is defined by an access price, a usage allowance, and a marginal price for any usage in excess of the allowance.

Despite the prevalence of three-part tariffs in practice, there has been little research on the determinants of consumer choice and demand in such environments (for exceptions see *Iyengar* 2005 and *Reiss and White* 2005). Most of the literature on nonlinear pricing instead focuses on two-part tariffs (see among others *Narayanan, Chintagunta and Miravete* 2005, *Danaher* 2002, *Essegaier, Gupta and Zhang* 2002, *Miravete* 2002, *Kling and van der Ploeg* 1990, and *Train, McFadden and Ben-Akiva* 1987). A two-part tariff does not include a usage allowance and the consumer encounters a constant marginal price independent of her usage. In contrast, the allowance of a three-part tariff implies that the consumer's marginal price under a given tariff depends on her usage: The marginal price is zero in case her usage remains within the allowance but is positive in case her usage exceeds the allowance. We therefore expect consumer behavior to be different under two-part and three-part tariff pricing.

When consumers sign up for a subscription-based service, such as cell phone usage or Internet access, they do not know the exact amount, e.g. in minutes or megabyte, they are going to use in the following billing period. Instead they commit to a tariff based on their expected usage and their typical month-to-month variation in usage. They then realize their actual usage during the billing period. This temporal separation of decision making and consumption has different implications for the consumer's bill under two-part tariffs and under three-part tariffs. For a two-part tariff, the bill fluctuates with the consumer's usage. If deviations from expected usage are symmetrically distributed, the consumer incurs on average the same charges under certain and uncertain demand. Under three-part tariff pricing, however, the consumer purchases a usage allowance for the access price and usage variation only affects charges if usage exceeds the allowance, leaving the total bill unchanged otherwise. Usage variation is therefore more likely to increase than to decrease a consumer's bill on a chosen tariff. If the magnitude of this asymmetric effect of demand uncertainty on charges is large, the consumer prefers a tariff with a higher allowance than the one she would choose purely based on average usage. An asymmetric distribution of monthly usage deviations can further amplify the effect of demand uncertainty on tariff choice. Consequently, under three-part tariff pricing both average usage and usage uncertainty affect tariff choice. For the provider, pricing decisions based only on consumers' expectations of their average usage ignoring their expectations of variation in usage would likely be sub-optimal.

The usage allowance introduces an additional dimension into the provider's pricing problem. For example, in order to make a tariff more attractive, a provider can change not only the access or the usage price, but also the allowance. This flexibility improves the provider's ability to match consumers' heterogeneous tastes, thereby helping reduce customer attrition and increase profit. Since models of two-part pricing by definition abstract from an allowance, their ability to shed light on consumer behavior and its consequences on pricing under three-part tariffs is limited.

In this paper, we aim at empirically exploring consumer behavior under three-part tariffs based on tariff choice and usage data of a German Internet service provider. We have three objectives: (i) We determine how usage uncertainty impacts 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 usage price and the allowance and thus explore consumers' responsiveness to all elements of a three-part tariff. (iii) We derive implications for pricing from the provider's perspective.

To appropriately account for consumer behavior under three-part tariffs, a model needs to incorporate both the consumer's discrete tariff choice given her uncertain usage and the subsequent continuous usage decision. Building upon the literature on discrete/continuous choice models (*Hanemann* 1984; *Dubin and McFadden* 1984; *Hausman, Tardiff and Belinfante* 1993), we develop a model of the consumer's decision process under three-part tariff pricing. We relax three assumptions inherent in previous work. First, we account for consumer uncertainty about usage at the time of tariff choice, as in the two-part tariff model in *Narayanan et al.* 2005. Our model reflects the lag between plan choice and usage occasions that is typical of communications services pricing. Second, recent research has shown that consumers have tariff-specific preferences, in particular preferences for flat-rate tariffs (*Train et al.* 1987; *Nunes* 2000; *Lambrecht and Skiera* 2006). We therefore allow for tariff-specific preferences in tariff choice. Third, we explicitly model a consumer's decision to switch to another provider.

In contrast to most research in subscription services that focuses on demand under monopoly, this significantly increases our model's applicability to competitive industries such as Internet access, wireless phone service, or car rental. We estimate the model based on an extensive set of usage data from a German Internet service provider for 10,715 consumers. We estimate tariff choice and usage elasticities and analyze the impact of demand uncertainty on consumers' tariff choice, expected bill, and consumer surplus. From the provider's perspective, we analyze the revenue impact of demand uncertainty. Based on our results we derive implications for pricing and customer management under three-part tariffs.

The remainder of the paper is organized as follows. We first introduce our data. Next, we develop and estimate a model of consumer tariff choice and usage under three-part tariff pricing. We then discuss the model results. We analyze how allowance, access price and usage price impact tariff choice and assess the implications of demand uncertainty from the consumer's and the provider's perspective. We conclude with a discussion of the implications of the findings for pricing.

2 Data

Our analysis is based on confidential usage data from a German Internet service provider for a sample of 11,717 customers with DSL Internet access and consumer demographics (Table 1). For a subset of consumers we have a total of five monthly usage observations. 7.6% of the customers self-identify as business customers. Since the provider targets primarily residential consumers and does not offer specific business tariffs, these customers are likely small businesses run out of the home whose Internet use covers both business and personal use. We include these households in our sample, but control for differences in usage patterns.

Table 1: User Demographics

Characteristic	Value	Frequency	Average usage	Std. dev. of usage
Customer	Residential	92.4%	2,025	838
	Business	7.6%	1,854	939
Gender	Male	88.0%	2,056	866
	Female	11.0%	1,718	720
	Missing value	1.0%	1,303	506
Age	below 20	2.0%	2,967	1,267
	20-30	24.4%	3,232	1,310
	30-40	38.7%	1,691	748
	40-50	21.7%	1,618	642
	50-60	9.3%	1,289	586
	60-70	3.1%	687	350
	70-80	0.4%	702	307
	Missing value	0.4%	3,314	1,946
Education	High school	4.6%	2,667	1,190
	Apprenticeship	25.1%	2,284	908
	Bachelor (Fachhochschule)	14.5%	1,524	686
	Master	19.2%	1,378	624
	Missing value	36.6%	2,269	944
Occupation	Not working	6.6%	1,988	742
	Self-employed	13.3%	1,897	832
	White and blue collar	53.4%	1,854	769
	Public sector	7.0%	1,389	638
	Apprenticeship, military/ civil service, school student	7.1%	3,200	1,320
	University student	12%	2,515	1,106
	Missing value	0.4%	1,646	719
Number of people in household	1	34.6%	2,269	990
	2	25.0%	1,685	679
	3	16.8%	2,154	940
	4	16.4%	1,810	701
	5	4.8%	1,959	834
	6	2.2%	2,178	868
	Missing value	0.0%	2,383	1,172
Number of children in household	0	58.2%	2,007	846
	1	13.6%	2,060	920
	2	12.4%	1,821	686
	3	3.6%	1,703	705
	4	1.9%	1,809	715
	Missing value	10.5%	2,339	1,015

N=11,717

For Internet access, consumers can choose between narrowband (dial-up) and broadband Internet access. In Germany, DSL is virtually the only broadband Internet access technology, with only 2% of broadband users using other technologies such as cable. The four largest providers hold a combined 73% of the market as of September 2004 (*Forrester Research* 2005). Internet access is provided on a monthly basis. The customers do not enter into long-term contracts with the provider, so a reassessment of tariff or provider choice is possible in any given month.

In a given month, each customer in our data set can disconnect her service with the provider or, alternatively, choose one of three tariffs offered by the provider. Tariff 1 has an access price and a monthly allowance. For usage exceeding the allowance, a marginal usage price is charged per megabyte (MB) transmitted. Tariff 2 has a higher access price and a higher allowance than tariff 1, but the same marginal usage price for usage exceeding the allowance. Tariff 3 is a flat-rate tariff with unlimited usage. We cannot tabulate the tariffs' actual prices and allowances due to confidentiality requirements; however, usage 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 2 illustrates consumers' tariff switching behavior within the current provider's tariff menu. We also observe consumers leaving the current provider. The overall attrition rate is similar to industry-wide rates of about 1.8% per month (*Gupta, Lehman and Stuart* 2004). Similar to the provider under consideration, competitors offer menus of tariffs that are defined in terms of usage in MB. We collect data on tariff offerings of major competitors that are available during the consumer's billing period and classify competitors' tariffs into tariffs with a low allowance, tariffs with a medium allowance, and flat-rate tariffs and report average prices and allowances in Table 3. Observing actual competitive tariffs allows us to model a consumer's decision to switch providers in detail.

Table 2: 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%	

Table 3: 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			

We next present an overview of consumers' tariff choices and usage patterns in the data set to motivate the development of our discrete/continuous choice model. In our set of usage data, the average customer transmits 2,012 MB per month (Table 4); however usage varies significantly with a standard deviation of 6,008 MB. The standard deviation in usage per consumer is on average 846 MB indicating that within-consumer usage varies significantly across time as well. As Figure 1 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 in transmission activity for 60.9% (52.8%) of usage observations, whereas for only 5.1% (5.0%) of observations usage is 150% or more of the allowance. 34.0% (42.2%) of users remain within plus or minus 50% of the allowance. The usage distribution shows a small mass point where usage equals exactly the allowance. In addition, many consumers use less than their tariff's allowance. If consumers indeed choose their tariff based on both usage uncertainty and average usage, they are more likely to choose a tariff with a higher allowance and access price than if deciding exclusively based on their average usage, even though their usage on average falls short of the allowance.

Table 4: Descriptive Statistics, 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

Figure 1: Usage as Percentage of Allowance, Tariffs 1 and 2

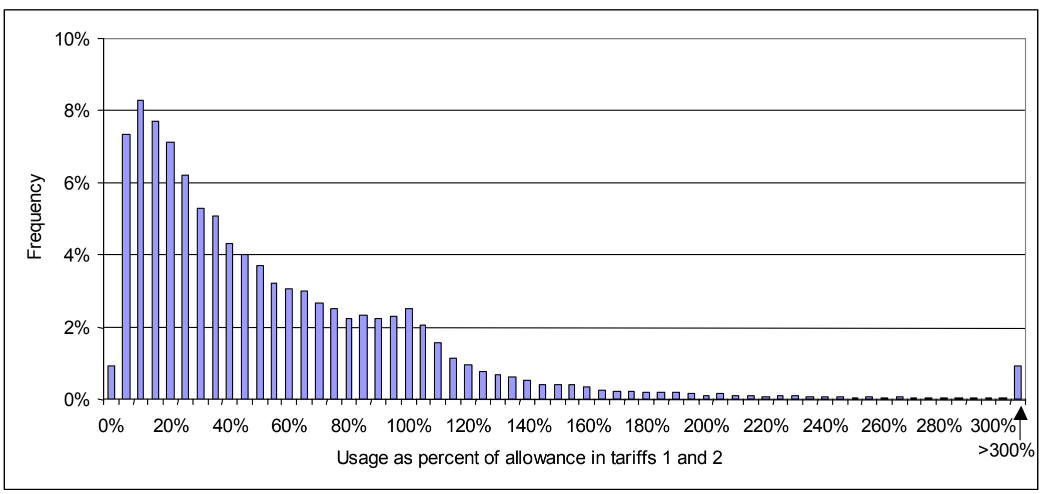


Table 5 illustrates the extent to which consumers choose the least costly tariff based on their ex-post usage. The rows list the chosen tariff, while the columns list the bill-minimizing tariff for the consumer's realized usage in her first available billing period. The sum of the columns thus represents all consumers on a particular tariff. The diagonal thus represents consumers who have chosen a tariff that minimizes their bill in that billing period. Consumers in the entries below the diagonal have chosen a tariff with an access price and a monthly allowance above that of the ex-post bill-minimizing tariff, a fact that the literature has coined a "flat-rate bias" (*Train et al.* 1987; *Nunes* 2000; *Winer* 2005; *Lambrecht and Skiera* 2006). In contrast, consumers in cells above the diagonal have chosen a tariff with an access price and an allowance that is below their ex-post bill-minimizing tariff. Across chosen tariffs, between 6.9% and 63.5% of consumers' choices does not correspond to the bill-minimizing tariff. Further, a high fraction of customers chooses a tariff with an access price above that of the ex-post bill-minimizing tariff. Only a small percentage of observations choose a tariff with an access price below that of the ex-post bill-minimizing tariff.

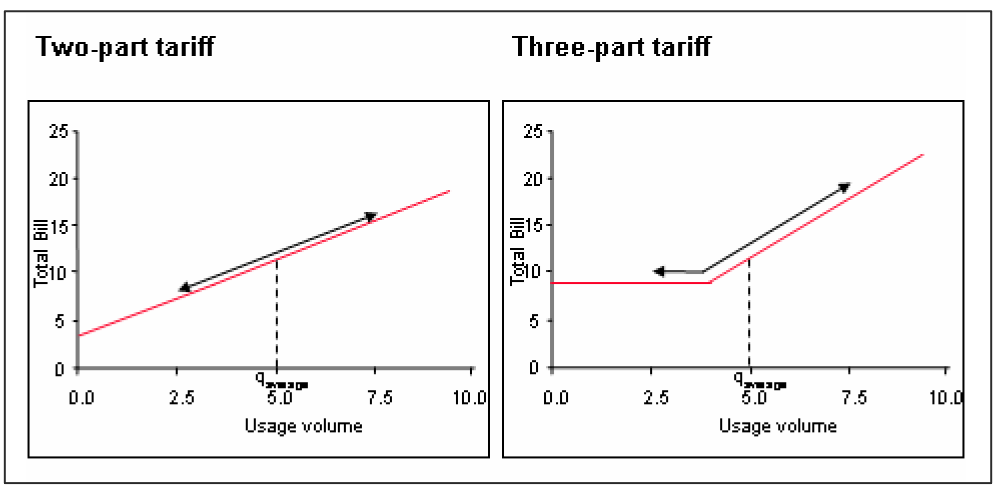
Table 5: Tariff-choice Biases

		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%

N=11,717

Since the consumer chooses a tariff at the beginning of the billing period before using the service, the choice takes into account only the possible demand realizations. If the disutility from incurring additional usage charges beyond the access price ex-post is large, the consumer has an incentive to choose a tariff with an allowance that exceeds the ex-post bill-minimizing tariff's allowance. As Figure 2 shows, a symmetrically distributed usage shock shifts both usage and total bill symmetrically under two-part tariff pricing. The expected bill is unaffected by the degree of a consumer's usage uncertainty. Similar to the two-part tariff environment, the usage shock shifts demand symmetrically under three-part tariff pricing. However, the total bill does not fall with usage once usage is below the allowance. A symmetrically distributed usage shock is more likely to increase than to decrease a consumer's bill. For two consumers with identical average usage, the expected bill of the consumer with high demand variation is higher than the expected bill of the consumer with low demand variation. These differences in the expected bill impact a consumer's choice between three-part tariffs and in particular lead consumers with high usage variation to choose a tariff with a higher access price and allowance than their counterparts with low usage uncertainty. One explanation for the results of our descriptive analysis above, which is based on ex-post usage, is that the choice of a tariff with a higher access price and allowance is optimal for the consumer ex-ante, while deviations from ex-post optimal behavior reflect demand uncertainty. The demand model in Section 3 recognizes the ex-ante decision process in more detail.

Figure 2: Effect of Uncertainty under Two-Part and Three-Part Tariff Pricing



The previous literature also proposes tariff-specific preferences and cognitive mistakes as factors that steer consumers to a tariff with a higher access price and allowance than is necessary ex-post. They are of importance if consumers prefer a tariff that leads to fewer month-to-month fluctuations in their bill, simplifying budgeting and financial planning or if consumers derive higher utility from not being charged an additional usage price (*Lambrecht and Skiera* 2006). Other work has identified situations where households systematically overestimate their usage (*Nunes* 2000; *DellaVigna and Malmendier* 2005). In our empirical work, we incorporate tariff-specific preferences, but do not investigate the source of such preferences further. We focus on demand uncertainty in explaining consumers' tariff choices.

To further investigate the role of demand uncertainty and motivate the model presented in Section 3, we conduct a regression analysis of factors that drive tariff choice. We focus on the subset of consumers who we observe for five months and analyze their choices in the last month in which they appear in the data. We measure demand uncertainty using the coefficient of variation of usage at the consumer level. We analyze the consumer's choice between the two three-part tariffs and the flat-rate tariff in a multinomial logit model. Table 6 shows the results using tariff 2 as the comparison group.

The first model analyzes the impact of average usage and coefficient of variation only on tariff choice, while model 2 also incorporates demographics. The included demographics are insignificant in explaining the choice among the three tariffs, with the exception of business customers being more likely to choose a flat-rate tariff than either of the two three-part tariffs. The results confirm the likely impact of demand uncertainty on tariff choice: a higher coefficient of variation increases the likelihood of choosing the flat-rate tariff, relative to the intermediate tariff, whereas a lower coefficient of variation increases the likelihood of choosing the tariff with the lowest allowance, tariff 1, over tariff 2. The results on drivers of tariff choice are both statistically and economically significant.

The marginal effect of an increase in average usage by 1 gigabyte, which is approximately one standard deviation of consumer usage, on the choice of tariff 1 is 10.1 percentage points. An increase in usage for a given standard deviation in usage also decreases the coefficient of variation, which counters the effect of the increase in usage on the likelihood of choosing tariff 1. The net effect of a 1 gigabyte increase in usage on the likelihood of choosing tariff 1 is a decrease by 9.6 to 9.7 percentage points. An increase in the standard deviation of usage by 2 gigabytes, the typical variation in standard deviations across consumers' usages, decreases the likelihood of tariff 1 being chosen by 2.9 to 3.7 percentage points through the increase in the coefficient of variation.

Table 6: Impact of demand uncertainty on tariff choice

	Model 1			Model 2		
	Coeff.	Std. Err.	Marg. Eff.	Coeff.	Std. Err.	Marg. Eff.
Tariff 1						
Average usage⁺	-0.974	0.037 ***	-0.101	-0.988	0.039 ***	-0.101
Coeff. variation	-0.266	0.152 *	-0.032	-0.208	0.156	-0.025
Business				-0.516	0.166 ***	-0.067
Female				-0.131	0.167	-0.012
Age				-0.005	0.005	-0.001
Household size				-0.014	0.037	-0.001
Occupation						
School student				0.048	0.196	0.001
University student				0.134	0.166	0.013
Educational Attainment						
Apprenticeship				0.012	0.090	0.001
Bachelor's degree (Fachhochschule)				-0.107	0.098	-0.009
Master's degree				0.098	0.095	0.009
Constant	3.882	0.115 ***		4.262	0.257	
Flat-rate tariff						
Average usage⁺	0.309	0.035 ***	0.005	0.337	0.038 ***	0.005
Coeff. variation	1.227	0.367 ***	0.007	1.276	0.382 ***	0.005
Business				0.786	0.426 *	0.008
Female				-0.512	0.704	-0.001
Age				0.017	0.017	0.000
Household size				0.002	0.115	0.000
Occupation						
School student				0.839	0.545	0.004
University student				-0.109	0.600	-0.001
Educational Attainment						
Apprenticeship				0.113	0.274	0.000
Bachelor's degree (Fachhochschule)				-0.474	0.345	-0.001
Master's degree				0.368	0.293	0.001
Constant	-4.343	0.332 ***		-5.097	0.804	
Log Likelihood		-1,816.005			-1,740,623.000	
N=		6,342			6,215	

Tariff 2 is the comparison group

*** p>0.01, **p>0.05, * p>0.1; ⁺Average usage measured in gigabyte (1 gigabyte = 1,024 megabyte)

The first results from the analysis of usage uncertainty and tariff-specific preferences illustrate their potential importance in the choice of three-part tariffs and point to possible differences in consumer behavior under two- and three-part tariffs. The coefficient of variation in monthly usage is, however, only an imperfect measure of usage uncertainty. It does not control for differences in pricing structures faced by the consumer across months due to changes in the allowance for tariff switchers or changes in the marginal price if usage exceeds the allowance only in some, but not all, months. The following section lays out a model of tariff choice and demand that explicitly accounts for these differences in pricing structure while allowing for demand uncertainty and tariff-specific preferences.

3 Model development and estimation

3.1 Model Set-up

Our model builds upon *Hanemann* 1984 who lays out a framework for analyzing demand problems that are mixtures of discrete and continuous choices. His framework applies both to discrete/continuous choice problems where the consumer's discrete tariff choice is contingent upon her continuous usage decision and to multiple discrete choice problems where the consumer decides how many units of a discrete good to purchase (*Kim, Allenby and Rossi* 2002; *Dubé* 2004; *Chan* 2003; *Hendel* 1999). Discrete/continuous choice problems have been estimated primarily in the context of demand for electricity (*Dubin and McFadden* 1984) and telecommunications. *Hausman et al.* 1993, for example, employ a discrete/continuous model of demand to estimate penetration of local phone service in the US. Due to a lack of data on usage, they estimate only the discrete portion of the model, but incorporate the continuous choice consistent with utility maximization. Similar to *Narayanan et al.* 2005 and *Economides, Seim and Viard* 2004, the availability of detailed, consumer-level usage data allows us to fully estimate the interplay between the discrete tariff and continuous usage decision, however in the context of three-part tariff pricing.

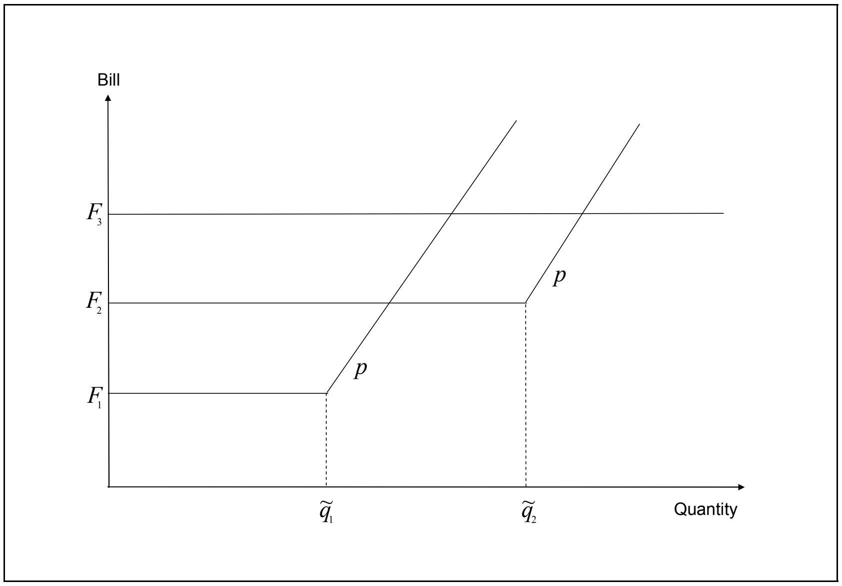
Each month, a consumer makes two decisions regarding Internet access. First, she chooses a tariff among the set offered by her provider or one of its competitors. The tariff choice is a discrete choice among the available tariffs and reflects expected usage for that period. For the choice among alternative tariffs offered by the same provider, we assume there are no switching costs between tariffs. This is reasonable as a consumer can switch her tariff online.

Conditional on the tariff choice, the consumer then makes a continuous usage decision about the quantity to consume. The model for consumer demand thus incorporates the two separate decisions and the interdependence of tariff choice and (expected) consumption.

3.1.1 Utility Function

The consumer has a choice between a set of J three-part tariffs. Each pricing plan is defined by a monthly access price, denoted by F_j for tariff j, a usage allowance measured in megabyte (MB) of data transmission included in the tariff at no additional charge, $\tilde{q}_j$, 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 generally associated with a higher allowance, so that $F_j < F_k$ if $\tilde{q}_j < \tilde{q}_k$. For the tariffs offered by the provider under consideration, for example, consumers have a choice between two three-part tariffs, denoted by tariffs 1 and 2 and one flat-rate tariff, with an unlimited usage allowance or $\tilde{q} = \infty$, so that $F_1 < F_2 < F_3$ and $\tilde{q}_1 < \tilde{q}_2 < \tilde{q}_3 = \infty$. The pricing structure offered by the provider uses a marginal price for usage exceeding the allowance that is identical for tariffs 1 and 2. Such constant usage prices across tariffs are also commonly used by the remaining providers in the industry and by wireless telecommunications providers, car rental companies, and other electronic content providers. Figure 3 illustrates the tariff structure used by the provider.

Figure 3: Tariff structure



We assume that consumer i making a choice of tariff j at time t maximizes the following quadratic utility function:

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

with

q_{ijt} – usage of DSL Internet access,

q_{Oit} – consumption of outside good,

ς_{ijt} – observable and unobservable consumer and plan-specific characteristics,

b – demand slope,

c_i – marginal utility of income,

d_{it} – demand intercept.

The consumer chooses consumption levels for q_{ijt} and q_{Oit} that maximize her utility subject to the budget constraint

(2) $y_{it} = q_{Oit} + F_j + (q_{ijt} - \tilde{q}_j) p_j$

where the price of the outside good has been normalized to one. p_j is equal to zero for $q_{ijt} \leq \tilde{q}_j$ and on a flat-rate tariff and strictly positive otherwise. This entails a demand for usage q_{ijt}, conditional on choice of tariff j, of

(3) $q_{ijt} = d_{it} - bp_j$.

The associated conditional indirect utility function is given by

(4) $V_{ijt}(y_{it}, p_j, F_j) = c_i \left[y_{it} - F_j + p_j \tilde{q}_j - \left(d_{it} - \frac{1}{2} bp_j \right) p_j \right] + \varsigma_{ijt}$.

If the customer's usage volume q_{ijt} is below the allowance $\tilde{q}_j$, equations (3) and (4) simplify significantly, but continue to imply bounded demand for usage.

3.1.2 Tariff Choice

A consumer's tariff choice is a function of tariff-specific preferences, ς_{ijt}. 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. We assume that $\vec{\varepsilon}_{it}$ is distributed according to probability distribution $P(\vec{\varepsilon}_{it})$.

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

We include observable and unobservable preference shifters to account in a reduced form for tariff- and provider-specific preferences identified in previous research (*Nunes* 2000, *Lambrecht and Skiera* 2006). We measure a consumer's inherent preference for a flat-rate tariff beyond usage considerations by including the observed preference shifter I_j^{FR}. I_j^{FR} is an indicator variable that is one if tariff j is a flat-rate tariff.

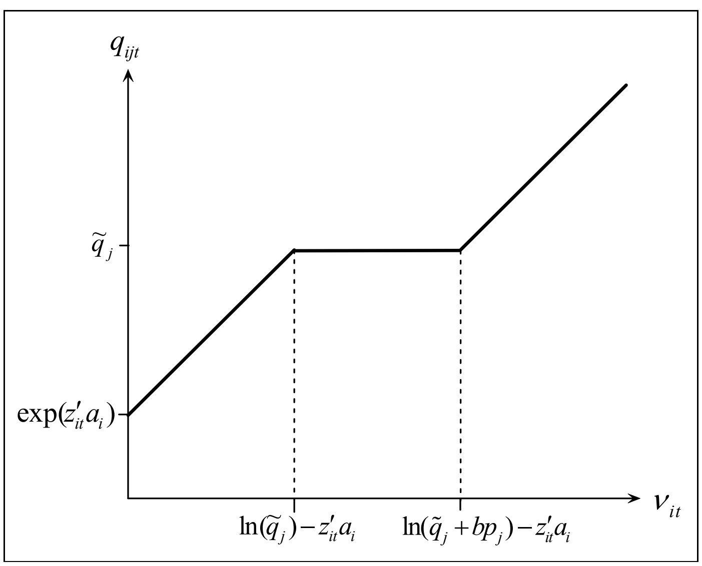
We allow for differential preference of the flat-rate tariff by business and residential customers by including an interaction between the flat-rate tariff indicator and the business customer indicator, $I_j^{FR}BUS_i$. In addition, we measure a preference for the current provider that reflects perceived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

A consumer chooses her tariff based on her expected usage before making her usage decision. We allow for consumer uncertainty over usage at the time of tariff choice. We incorporate a usage shock, ν_{it}, into the consumer's demand to reflect random variation in usage, which we assume to be normally distributed with mean zero and standard deviation $\sigma_{\nu i}$. The consumer knows the demand shock initially only in distribution. She observes her usage shock in the second stage before making her actual usage decision. However, the usage shock is unobserved by the researcher throughout. To ensure that the demand system is well specified, the usage shock ν_{it} shifts the conditional demand function as follows:

$$\begin{aligned} d_{it} &= \exp(z_{it}'a_i + \nu_{it}) \\ q_{ijt} &= \exp(z_{it}'a_i + \nu_{it}) - bp_j. \end{aligned} \tag{6}$$

where z_{it}' denotes a vector of consumer characteristics and time trends that affect demand, such as household size, age, or gender. For given household 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 ν_{it} below $\ln(\tilde{q}_j) - z'_{it}a_i$, 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 $[\ln(\tilde{q}_j) - z'_{it}a_i, \ln(\tilde{q}_j + bp_j) - z'_{it}a_i]$, usage exceeds the allowance of $\tilde{q}_j$ at a marginal price of zero. At the then applicable positive marginal price, optimal usage q_{ijt} falls short of $\tilde{q}_j$. Therefore, we set q_{ijt} equal to $\tilde{q}_j$ for usage shocks in the interval $[\ln(\tilde{q}_j) - z'_{it}a_i, \ln(\tilde{q}_j + bp_j) - z'_{it}a_i]$. Figure 4 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. The usage mass at $\tilde{q}_j$ depends on the variance of the usage shock. The fact that in practice, there is large variation in individual consumer usage over time (Table 4) and the mass point of consumers using 100% of their allowance is small (Figure 1) suggests that the variance in unexpected usage shocks is large.

Figure 4: Mapping from Usage Shock to Usage, Three-Part Tariff



We define $x_{ijt} = \dfrac{\ln(\tilde{q}_j + bp_j) - z'_{it}a_i}{\sigma_{vi}}$ as the normalized ν_{it} cutoff such that consumption exceeds the allowance for $\dfrac{\nu_{it}}{\sigma_{vi}} > x_{ijt}$. Substituting the expression for the demand intercept into the indirect utility function then yields:

$$\text{(7)} \quad V_{ijt}(y_{it}, p_j, F_j) = \begin{cases} c_i \left[y_{it} - F_j \right] + \varsigma_{ijt} & \nu_{it} \le \sigma_{vi} x_{ijt} \\ c_i \left[y_{it} - F_j + p_j \tilde{q}_j - \left(\exp(z'_{it}a_i + \nu_{it}) - \dfrac{bp_j}{2} \right) p_j \right] + \varsigma_{ijt} & \nu_{it} > \sigma_{vi} x_{ijt} \end{cases}.$$

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 econometrician), the expectation is taken only with respect to the usage shock, ν_{it}. The expected utility from consuming on a three-part tariff is:

$$\begin{aligned} \mathrm{E}[V_{ijt}] &= \Pr(q_{ijt} \le \tilde{q}_j)\ \mathrm{E}[V_{ijt} \mid q_{ijt} \le \tilde{q}_j] + \Pr(q_{ijt} > \tilde{q}_j)\mathrm{E}[V_{ijt} \mid q_{ijt} > \tilde{q}_j] \\ &= \Pr(q_{ijt} \le \tilde{q}_j) c_i (y_{it} - F_j) + \Pr(q_{ijt} > \tilde{q}_j) \\ \text{(8)} \qquad & \qquad c_i \left[y_{it} - F_j + p_j \tilde{q}_j + \frac{1}{2} bp_j{}^2 - \widehat{z'_{it}a_i} \mathrm{E}\left(\hat{\nu}_{it} \mid q_{ijt} > \tilde{q}_j \right) p_j \right] + \varsigma_{ijt} \\ &= \mathrm{E}[\overline{V}_{ijt}] + \varsigma_{ijt}. \end{aligned}$$

In equation (8) and the following exposition, a variable with a hat denotes the exponential of the original variable, for example $\hat{\nu}_{it} = \exp(\nu_{it})$. Equation (8) 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 charges of p_j for each additional MB of usage in addition to the access price. From equation (6) we derive the expected value of $\hat{\nu}_{it}$ given that $q_{ijt} > \tilde{q}_j$:

$$\text{(9)}\quad \begin{aligned} \mathrm{E}\left[\hat{v}_{it} \mid q_{it} > \tilde{q}_j\right] &= \mathrm{E}\left[\hat{v}_{it} \middle| \exp(z'_{it}a_i + v_{it}) - bp_j > \tilde{q}_j\right] \\ &= \mathrm{E}\left[\hat{v}_{it} \middle| \hat{v}_{it} > \frac{\tilde{q}_j + bp_j}{\widehat{z'_{it}a_i}}\right] = \mathrm{E}\left[\hat{v}_{it} \middle| \hat{v}_{it} > \widehat{\sigma_{vi}x}_{ijt}\right] \end{aligned}$$

The conditional distribution of $(\hat{v}_{it} \mid \hat{v}_{it} > \widehat{\sigma_{vi}x}_{ijt})$ follows a left truncated lognormal distribution with an expected value of

$$\text{(10)}\quad \mathrm{E}\left[\hat{v}_{it} \mid \hat{v}_{it} > \widehat{\sigma_{vi}x}_{ijt}\right] = e^{0.5\sigma^2} \frac{\Phi\left(\sigma_{vi} - x_{ijt}\right)}{\Phi(-x_{ijt})},$$

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

$$\text{(11)}\quad \Pr(q_{ijt} \le \tilde{q}_j) = \Pr\left[v_{it} \le \sigma_{vi}x_{ijt}\right] = \Phi(x_{ijt}) .$$

Therefore,

$$\text{(12)}\quad \begin{aligned} \mathrm{E}[V_{ijt}] = {} & \Phi(x_{ijt})c_i(y_{it} - F_j) + \left(1 - \Phi(x_{ijt})\right)c_i \\ & \left[y_{it} - F_j + p_j\tilde{q}_j + \frac{1}{2}bp_j^{\,2} - e^{0.5\sigma_{vi}^2}\widehat{z'_{it}a_i}\frac{\Phi(\sigma_{vi} - x_{ijt})}{\Phi(-x_{ijt})}p_j\right] + \varsigma_{ijt}. \end{aligned}$$

Given that the marginal price, p_j, of a flat-rate tariff is equal to zero, the expected conditional indirect utility of a flat-rate tariff is simply

$$\text{(13)}\quad \mathrm{E}[V_{ijt}] = c_i\left(y_{it} - F_j\right) + \varsigma_{ijt} .$$

The tariff choice is governed by the variance of the consumer's usage shock σ_{vi}^2 and the relative costs of the tariffs. For example, in choosing among two three-part tariffs, a consumer prefers tariff 1 to tariff 2 if the expected conditional indirect utility of tariff 1 exceeds the one of tariff 2 or $\mathrm{E}[V_{i1t}] \ge \mathrm{E}[V_{i2t}]$. This entails that the consumer chooses tariff 1 if

(14)

$$\frac{\varsigma_{i1t}-\varsigma_{i2t}}{c_i}-(F_1-F_2)\geq p_1\left(\tilde{q}_2(1-\Phi(x_{i2t}))-\tilde{q}_1(1-\Phi(x_{i1t}))\right)+0.5bp_1{}^2\left(\Phi(x_{i1t})-\Phi(x_{i2t})\right)$$

$$+e^{0.5\sigma_{vi}^2}p_1\widehat{z_{it}'a_i}\left(\frac{\Phi(\sigma_{vi}-x_{i1t})}{\Phi(-x_{i1t})}\left(1-\Phi(x_{i1t})\right)-\frac{\Phi(\sigma_{vi}-x_{i2t})}{\Phi(-x_{i2t})}\left(1-\Phi(x_{i2t})\right)\right).$$

The consumer trades off certain benefits in the form of tariff-specific preference gains and savings from choosing a lower access price (left-hand side) versus the uncertain utility losses due to possible charges for usage in excess of the allowance (right-hand side). The uncertain component depends on the variance of the usage shock and the likelihood of remaining within the usage allowance. The higher the variance in expected usage the more likely it is that the consumer prefers tariffs with a higher allowance of data transmission. This is particularly apparent in comparing the expected utilities of one of the two three-part tariffs to the one of the flat-rate tariff. A consumer prefers tariffs 1 or 2 to the flat-rate tariff 3 provided

$$(15)\qquad \frac{\varsigma_{ijt}-\varsigma_{i3t}}{c_i}-(F_j-F_3)\geq p_j\left(e^{0.5\sigma_{vi}^2}\widehat{z_{it}'a_i}\frac{\Phi(\sigma_{vi}-x_{ijt})}{\Phi(-x_{ijt})}-\frac{1}{2}bp_j-\tilde{q}_j\right)\left(1-\Phi(x_{ijt})\right),$$

that is if the preference gain from tariffs 1 or 2 relative to the flat-rate tariff and the certain savings from choosing a lower access price exceed the uncertain payouts in case she exceeds her allowance on those tariffs. For tariff 1 or 2 to be the optimal choice, households with high usage variation need to have a high preference for these plans. Alternatively, the tariffs' access prices need to be significantly below that of the flat-rate tariff to offset the utility penalties associated with exceeding the tariffs' associated allowances. Consistent with these tradeoffs, we show below that for the average household in our data set, the probability of choosing a flat-rate tariff increases with $\sigma_{\nu i}$.

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

3.1.3 Provider switching

In the data, we observe not only tariff and consumption choices by existing consumers, but also consumers who decide to leave the provider. One option to model the consumer's decision to leave the provider is to assume that she disconnects her service completely. Under this assumption, the value of leaving the provider is simply normalized to zero, as in *Iyengar* 2005. This approach has the advantage of being easy to implement in model estimation. However, it probably does not fully reflect consumers' actual Internet access choices. Prior to subscribing to DSL Internet access, consumers had to pay a fixed fee of EURO 100 - 200 for modem and installation. Given both this upfront investment and the preference for higher transmission speed that consumers are likely to develop, 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, consumer attrition can be incorporated by allowing each consumer a choice among not only the company's three tariffs, but also those of the largest competing providers in the market. Similar to *Israel* 2005, we assume that each month a consumer becomes aware of the menu of tariffs offered by one competitor and takes this set of tariffs into account in her tariff choice. This is for example the case if the consumer views an online or offline ad of a competing provider. We randomly choose one of the competing providers' tariff offerings that are available at the beginning of the consumer's billing period and include the tariffs in the consumer's choice set. The consumer then chooses not only between the three tariffs of the current provider but compares the expected indirect utility of choosing any of the competitor's tariffs with the expected indirect utility of remaining with the current provider. The advantage of this approach is that it limits the size of the choice set and keeps the consumer's problem more tractable than allowing her a choice among all competing tariffs.

In summary, we specify the consumer's initial tariff choice as a function of her expected usage, her usage variation and her tariff-specific preference shifters. The consumer chooses that tariff that maximizes her expected indirect utility in equations (12) and (13) where the choice set consists of all tariffs offered by the current provider and one randomly chosen competitor. The tariff choice incorporates the usage decision in expectation. After the tariff choice, the consumer then makes a usage choice, where demand follows the expression in equation (6).

3.2 Model estimation

We use a logit specification for our discrete/continuous choice model. The estimation of the model defined by equations (6), (12), and (13) proceeds via maximum likelihood. We allow for attrition by randomly assigning another provider's tariff offering to each consumer's choice set. For a consumer who chooses any tariff of the current provider we estimate provider, tariff, and demand choices. The likelihood of seeing a particular consumer's choices is the joint probability of her provider choice, I_{it}^{NC}, her plan choice conditional on remaining with the provider, $I_{ijt|NC}$, as a function of expected usage, and her usage, q_{ijt}, once usage uncertainty is resolved. For consumers who leave the provider, we do not observe the choice of a particular tariff and consequently estimate only the likelihood of attrition, which equals the probability that the consumer chooses any one of the competing providers' tariffs, or the sum of the choice probabilities for each competitive tariff in the consumer's choice set. Consumer i's contribution to the likelihood, l_{it}, therefore equals:

(16)

$$l_{it} = \begin{cases} h(I_{it}^{NC}; a_i, b, c_i, \sigma_{vi}) f(I_{ijt|NC}; a_i, b, c_i, \sigma_{vi}) g(q_{ijt}; a_i, b, c_i, \sigma_{vi}) & \text{if } i \text{ chooses current provider} \\ 1 - h(I_{it}^{NC}; a_i, b, c_i, \sigma_{vi}) & \text{if } i \text{ leaves current provider} \end{cases}$$

where $h(I_{it}^{NC}; a_i, b, c_i, \sigma_{vi})$ denotes the likelihood that consumer i stays with the current provider in month t. $f(I_{ijt|NC}; a_i, b, c_i, \sigma_{vi})$ is the likelihood of observing consumer i's choice to be tariff j in month t, and $g(q_{ijt}; a_i, b, c_i, \sigma_{vi})$ denotes the likelihood of observing the normally distributed demand shock ν_{it} in equation (6). For any candidate values of the vector of parameters, $(a_i, b, c_i, \sigma_{vi})$, the probability that consumer i chooses tariff j in month t is given by the integral of the distribution function of plan preferences:

$$(17) \qquad \Pr(I_{ijt} = 1) = \int_{A_{ijt}} dP(\vec{\varepsilon}_{it}),$$

where $A_{ijt} = \{\vec{\varepsilon}_{it} \big| E[V_{ijt}] \geq E[V_{ikt}] \;\; \forall k \neq j\}$ is the set of $\vec{\varepsilon}_{it}$ such that tariff j provides maximal expected indirect utility, as defined in equations (12) and (13). Assuming that the tariff-specific preferences $\vec{\varepsilon}_{it}$ come from a type-1 extreme value distribution yields closed-form multinomial logit tariff choice probabilities. We allow the marginal utility of income, c_i, to vary by consumer by assuming that deviations from the average parameter values are distributed according to a mean-zero, independent Normal distribution with a variance of σ_c^2.

The advantage of the multinomial logit specification is that consumers' choice between varying options can easily be estimated. Since the logit specification restricts substitution patterns between choices, we estimate a multinomial probit model to test the robustness of the results. The probit model involves more complicated simulation techniques to derive choice probabilities. If we allowed for switching to a competing provider, the size of the choice set would be large and vary depending on which provider's tariffs make up each consumer's outside option. To incorporate this setup into a multinomial probit model with correlated normal choice errors, restrictions need to be imposed on the covariance structure of preferences for the competitor's tariffs. Given the great disparity in prices and allowances of competing providers' tariffs this does not seem appropriate. We therefore estimate the consumer's choice between the tariffs of the current provider and the option to disconnect completely, a total of four options.

We assume that $\vec{\varepsilon}_{it}$ is distributed according to a multinomial Normal distribution with a 4×4 variance-covariance matrix Σ_{ε}. We use simulation techniques to derive the multinomial probit choice probabilities, employing the GHK simulator with 200 draws per household (*Geweke, Hajivassiliou and Ruud* 1994).

Observing 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 for tariffs 1 and 2. The usage choices of observationally equivalent consumers under these two price levels identify the price coefficient.

4 Implications for pricing Internet access

4.1 Model results

Our model results include parameter estimates both for the logit and for the probit estimation. We use one observation for each household in the sample selecting each household's third billing period. This results in a total of 10,715 observations. Table 7 summarizes the results. Overall the two specifications yield similar parameter estimates.

The parameters for tariff choice confirm that consumers have a systematic preference for the flat-rate tariff relative to tariffs 1 and 2 as indicated by the significant parameter estimate of the flat-rate dummy. This preference is significantly stronger for business customers than for residential customers. In addition, the parameter estimates that capture provider preference (-9.422 and -9.948) indicate a strong preference for remaining with the current provider, consistent with the presence of state dependence or switching costs in the provider choice.

Based on their tariff choice consumers choose their usage. Of most interest in the analysis of the usage decision are the demand slope and the standard deviation of the usage shock, $\sigma_{\nu i}$. We find similar estimates in the logit and in the probit specification with values of the price coefficient *b* of 1.664 and 1.849, respectively. In a previous logit specification we also modeled *b* as a random coefficient, but found its standard deviation to be insignificant in estimation. These results indicate that usage falls in the usage price and that consumers do not strongly differ with regard to their usage price sensitivity.

We specify the standard deviation of the usage shock, $\sigma_{\nu i}$, as a function of household characteristics. In the probit specification, this is a linear function of household size, whereas in the logit specification we allow for $\sigma_{\nu i}$ to vary by further demographics, such as age, occupation and whether a customer uses the Internet for business purposes. We find the standard deviation of the usage shock, and thus demand uncertainty, to vary significantly across households. The standard deviation of the usage shock amounts to 141.6 MB for the logit model and 126.7 MB for the probit model for the average household. It ranges from 8.6 to 99% of predicted usage, with a mean of 18% and a standard deviation of 4.6%.

The standard deviation falls in household size, suggesting that high and low usage levels of different members of the household average out, and increases with age of the account holder. Hence, consumers are heterogeneous in the amount of usage uncertainty they experience. The results confirm our reasoning from Section 2 that unexpected usage shocks largely drive observed consumer demand. In the next section we explore in greater detail how demand uncertainty impacts tariff choice.

Turning to demographics we find that Internet usage significantly decreases with age and increases with household size. Usage is not statistically significantly different for the remaining demographic categories as well as for month-specific dummies.

Table 7: Parameter Estimates

	Logit estimation			Probit estimation		
	Estimate	Std. Err.		Estimate	Std. Err.	
Parameters for tariff choice						
Flat rate dummy	2.714	0.738	***	2.962	1.346	**
Interact. flat rate tariff - business	2.607	0.751	***	1.887	0.950	**
Provider Preference	-9.422	1.066	***	-9.948	1.085	***
Marginal utility of income, c	1.256	0.365	***	0.406	0.040	***
σ_c	0.479	0.143	***			
Variance-Covariance matrix $\Sigma = LL'$ [(1)]						
l_{32}				1.011	0.698	
l_{33}				1.105	0.415	***
l_{42}				0.508	1.160	
l_{43}				1.523	0.717	**
l_{44}				0.943	0.771	
Parameters for usage decision [(2)]						
Demand Intercept						
Constant	2.629	0.380	***	2.533	0.499	***
Age	-0.016	0.004	***	-0.004	0.002	*
Household size	0.053	0.016	***	0.004	0.026	
Occupation						
School student	-0.096	0.206		-0.032	0.060	
University student	-0.129	0.272		0.023	0.047	
Educational Attainment[(3)]						
Apprenticeship	0.035	0.165		0.012	0.232	
Bachelor's degree (Fachhochschule)	-0.127	0.151		-0.029	0.235	
Master's degree	-0.030	0.180		-0.034	0.230	
Female	0.018	0.145		-0.054	0.045	
Business	-0.218	0.259		-0.261	0.108	**
Non-work days per month	-0.001	0.021		-0.045	0.025	*
March	0.002	0.151		0.063	0.191	
April	-0.026	0.138		0.114	0.176	
May	-0.029	0.143		0.126	0.191	
Demand Slope						
b	1.664	0.855	*	1.846	0.499	***
Std. Deviation of Demand, σ_ν						
Constant	1.271	0.137	***	1.272	0.047	***
Household size	-0.025	0.010	**	-0.002	0.014	
Age	0.005	0.003	*			
Occupation: University student	0.067	0.128				
Occupation: School student	0.077	0.192				
Business	0.060	0.137				
Log-likelihood	-46,479.280			-44,804.124		

N=10,715 *** p<0.01, ** p<0.05, * p<0.1

(1) We estimate five elements l_{32}, l_{33}, l_{42}, l_{43}, l_{44} of the Choleski decomposition L of the variance-covariance matrix to capture the correlation structure of the multinomial normal errors. The remaining elements of L are normalized to $L(.,1) = L(1,.) = L(2,3) = L(2,4) = L(3,4) = 0$ and $L(2,2) = 1$.

(2) Monthly usage is measured in hundreds of megabytes.

(3) We control for missing values by including an indicator variable for households with missing information.

4.2 Responsiveness of consumer behavior to tariff changes

4.2.1 Results

Based on our parameter estimates, we estimate price elasticities for tariff choice and usage. Table 8 summarizes tariff choice and usage elasticities for the logit model. We find that the choice elasticity of tariff 1 with respect to the access price is –0.510. Demand for tariff 1 is much more inelastic than that of tariffs 2 and 3, with elasticities of –10.788 and –4.453, respectively. Given the estimated high preference for the chosen provider, the menu of plans offered by the provider is more attractive than switching to a competitor. Among those tariffs, consumers on tariff 1 can only switch to a tariff with a higher access price and allowance in response to a price increase. Thus, among tariff 1 users only those consumers with relatively high usage find such a switch attractive. We have shown above that this group of users is small as many tariff 1 customers use far less than the allowance. In contrast, when the access price of tariff 2 increases, consumers have the option to downgrade to tariff 1 or upgrade to tariff 3 to remain at comparable utility levels. Thus, the elasticity of tariff 2 is relatively high. Similar to consumers on tariff 2, consumers on the flat-rate tariff can downgrade their tariff to tariff 2 in response to an increase in access price, but cannot increase their utility by upgrading to a tariff with a higher allowance. This explains why the elasticity of the flat-rate tariff is below the elasticity of the three-part tariff. Whereas the elasticity with respect to the access price of the three-part tariff with the lowest access price is thus relatively low, the elasticity of the remaining tariffs is far higher and exceeds the elasticity of two-part tariffs. Previous work has found tariff choice elasticities under two-part tariffs for local telephone service from –0.46 to –2.19 (*Train et al.* 1987; *Danaher* 2002). The relatively high price elasticities also suggest that the provider does not choose profit-maximizing prices.

The tariff choice elasticity with respect to the usage price is –1.225 for tariff 1, and thus in absolute value higher than elasticities estimated by *Train et al.* 1987 in the range of –0.20 to –0.41, but similar to more recent results by *Narayanan et al.* 2005 of -1.0 to –1.8. A 1% usage price increase lowers the probability of choosing tariff 1 by 1.2%. Demand for tariff 2 is more elastic. A 1% increase in usage price decreases the tariff choice probability by 6.4%. Again, in contrast to consumers on tariff 1, consumers on tariff 2 can both upgrade and downgrade their chosen tariff explaining differences in elasticities between both tariffs. Changes in the access price, however, have much larger effects on the choice of tariff 2 than changes in the usage price.

We also find that usage is relatively inelastic to changes in the usage price, with average usage price elasticity across households of –0.068. 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, Wetzel and Mitchell* 1983; *Train et al.* 1987; *Hobson and Spady* 1988; *Kridel* 1988; *Kling and van der Ploeg* 1990; and *Kridel, Rappoport and Taylor* 2002) or as large as –1.70 to –2.50 (*Narayanan et al.* 2005).

In contrast to the analysis of two-part tariff pricing we can also provide results on the tariff choice elasticity with respect to changes in the allowance. We find elasticities of 0.461 for choice of tariff 1 and 5.453 for choice of tariff 2, indicating that in response to an increase in each tariff's allowance, consumers switch to the tariff, primarily from the neighboring tariff. Tariff 2's share increases proportionately more than tariff 1's since an increase in its allowance makes tariff 2 more attractive to consumers on both tariff 1 and the flat-rate tariff. In fact, increasing the allowance of tariff 1 and tariff 2 by 100 MB increases the respective tariff's overall share of consumers by 2.3% for tariff 1 and 10.9% for tariff 2.

In addition, we analyze the elasticity of usage with respect to changes in the allowance. We find elasticities of 0.295 for tariff 1 and 0.390 for tariff 2. This result is interesting from two perspectives. First, the effect of changes in the allowance on usage is larger than the effect of changes in usage price on usage (-0.068). This confirms that the allowance plays a relevant role in consumer behavior under three-part tariffs. Second, we find that changes in the allowance affect tariff choice more than usage which is in line with our previous results that the elements of a three-part tariff are particularly relevant in tariff choice but less in determining the actual usage volume.

Table 8: Summary of Price Elasticities

		Tariff			
Elasticity of	with respect to	Tariff 1	Tariff 2	Flat rate	Overall
Tariff choice	Access price	-0.510	-10.788	-4.453	
Tariff choice	Usage price	-1.225	-6.351		
Tariff choice	Allowance	0.461	5.453		
Usage	Usage price				-0.068
Usage	Allowance	0.295	0.390		

N=10,715

To further illustrate the effect of changes in the three components of a three-part tariff on consumer behavior we consider the effect of varying different components of the three-part tariffs on various consumer types. We vary the components such that the consumer bill changes by the same amount. First, consider a consumer whose usage is at 1,000 MB above the allowance on tariff 2. For this type of 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 on tariff 2. However, the increase of the access price decreases the predicted probability of choosing tariff 2 by 10.8% whereas the increase in usage price decreases the predicted probability of choosing tariff 2 only by 6.3%. Next, consider a low-usage consumer whose usage exceeds the allowance on tariff 1 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 on tariff 1. Lowering the access price, however, increases the probability of choosing tariff 1 by 1.8% whereas increasing the allowance increases the probability of choosing tariff 1 only by 0.5%. Results of both counterfactuals thus illustrate that under three-part tariff pricing consumers are particularly responsive to changes in the access price compared to changes in the allowance and in the usage price.

Our analysis of tariff choice and usage elasticities with respect to the three price components of a three-part tariff provides additional support that consumer behavior differs significantly under two- and three-part tariffs. Whereas a consumer's tariff choice and usage decision under a two-part tariff is driven by access and usage price, we find that these decisions in the context of three-part tariffs are primarily driven by access price comparisons and less so by allowance and usage price. One reason for this result is that under a three-part tariff, the average user assesses the probability of exceeding the allowance to be small and consequently chooses a tariff primarily based on the access price and the allowance but less so based on the usage price.

4.2.2 Implications

Our results on tariff choice and usage elasticities under three-part tariff pricing have two implications for the provider's pricing. First, the usage price does not significantly change either the initial tariff choice or the ex-post usage. A comparison of our results with results from previous studies on two-part tariff pricing suggests that the usage price is less important in determining demand under three-part pricing than under two-part pricing. Consequently, for the given pricing structure the results suggest that the provider's revenue potential lies primarily in changes of the allowance and the usage price. Second, when considering a decrease (increase) in the access price versus an increase (decrease) in the allowance, the provider needs to take into account the cumulative effect of such changes on consumer behavior across tariff offerings. For the tariff structure chosen by the provider, the effect of access price changes dominates any adjustment in behavior from changes in the usage allowance. Neither changes in the allowance nor changes in the usage price affect tariff choice very much.

4.3 Implications of uncertainty for consumer behavior and surplus and provider revenue

Our model estimation has shown that consumer demand uncertain is large, ranging from 8.6 to 99% of predicted usage, with a mean of 18%. In this section, we analyze the impact of demand uncertainty on consumer choice between three-part tariffs and the effect of changes in demand uncertainty on consumer welfare and provider revenue.

4.3.1 Results

To assess the role of unexpected demand fluctuations in the consumer's tariff choice, we first numerically simulate tariff choice elasticities with respect to changes in the standard deviation of the usage shock, $\sigma_{\nu i}$. We find that a 1% increase in $\sigma_{\nu i}$ decreases the probability of choosing tariff 1 by 1.404%, at the expense of a higher share of consumers who switch to tariffs 2 and 3, with elasticities of 2.940 and 1.813, respectively. These elasticities represent the net effect of both consumers switching from tariff 1 to tariff 2 and to the flat rate and consumers switching from tariff 2 to the flat rate in response to the higher demand variation. Our numerical results are thus in line with the expectation that a higher usage shock variance, $\sigma_{\nu i}$, leads to a higher likelihood of choosing a tariff with a higher allowance.

The usage shock that enters the indirect utility, $\hat{\nu}_{it} = \exp(\nu_{it})$, is log-normally distributed. As a result, an increase in the standard deviation of the underlying error, ν_{it}, increases the standard deviation as well as the expected value of $\hat{\nu}_{it}$, both of which affect the tariff-choice elasticities with respect to $\sigma_{\nu i}$. The above results thus account for both effects. To focus exclusively on the role of usage uncertainty, we also 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

$$q_{ijt} = (1+\alpha)\left[\exp(z_{it}'a_i)\exp(\nu_{it}) - bp_j\right] - \alpha \mathrm{E}(q_{ijt}), \text{ with}$$
$$\mathrm{E}(q_{ijt}) = \exp(z_{it}'a_i)\exp(0.5\sigma^2) - \left(1-\Phi(x_{ijt})\right)bp_j. \tag{18}$$

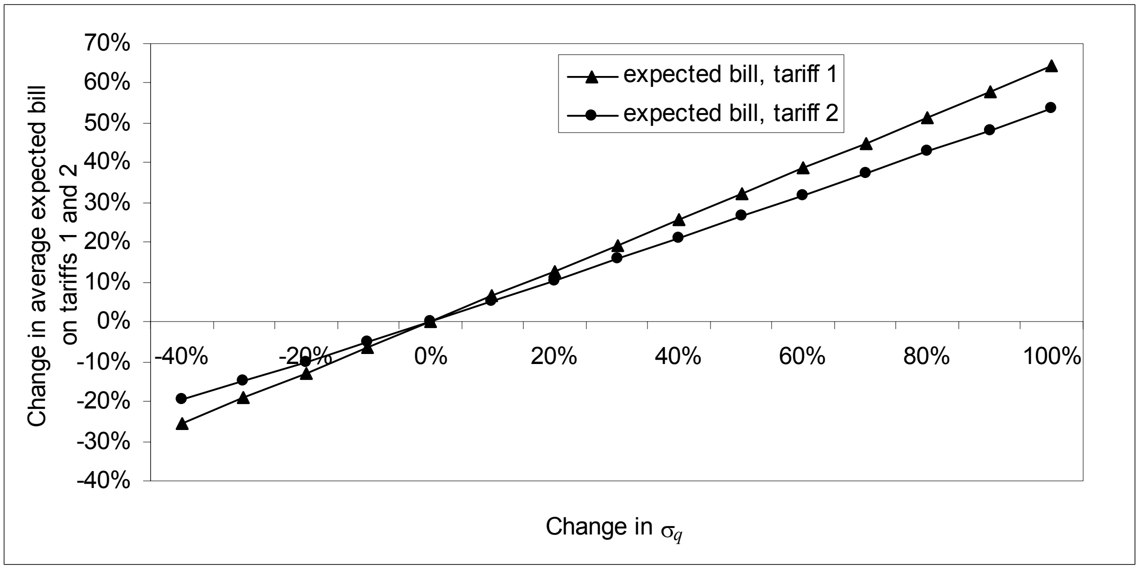
In this expression, α measures the percent change in the standard deviation of usage. For a value of $\alpha = 0$, the equation reduces to the original demand function in equation (6). By including the term $-\alpha \mathrm{E}(q_{ijt})$, we hold expected usage constant for increases or decreases in the standard deviation of usage. The results in Table 9 confirm that even with a constant expected usage, consumers are more likely to choose a tariff with a higher allowance as usage uncertainty increases. We find an elasticity of –0.304 for tariff 1, again balanced by positive elasticities of 0.391 and 0.425 for tariffs 2 and 3, respectively. This illustrates that with increasing uncertainty, consumers are more likely to switch to a tariff with a higher allowance and access price and ultimately to a flat rate tariff, which is in line with our expectations of consumer behavior under usage uncertainty. The comparison of these results to the tariff choice elasticities with respect to σ_{vi} illustrates the role of increases in expected usage shifting consumers to tariffs with higher allowances in the initial uncertainty elasticity. The elasticities that hold expected usage constant are smaller in magnitude, but are driven by similar considerations to the ones discussed above.

Table 9: Summary of Uncertainty Elasticities

		Tariff		
Elasticity of	with respect to	Tariff 1	Tariff 2	Flat rate
Tariff choice	Std dev of usage shock, σ_{vi}	-1.404	2.940	1.813
Tariff choice	Std dev of usage, σ_q	-0.304	0.391	0.425
N=10,715				

An increase in σ_q also affects a consumer's expected bill on the three-part tariffs 1 and 2. Figure 5 illustrates that averaged over all consumers, higher levels of σ_q, for constant expected usage, are associated with higher expected bill amounts. For example, an increase in the standard deviation of usage by 20% increases the expected bill on tariff 1 on average by 13%. This results from changes in expected usage conditional on exceeding the allowance and changes in the probability of exceeding the allowance. For usage below the allowance, the bill remains constant at the access price. The expected bill of a consumer on a three-part tariff increases in σ_q because of the asymmetric effect of usage variation on the billed amount.

Figure 5: Effect of changes in σ_q on average expected bill on tariffs 1 and 2

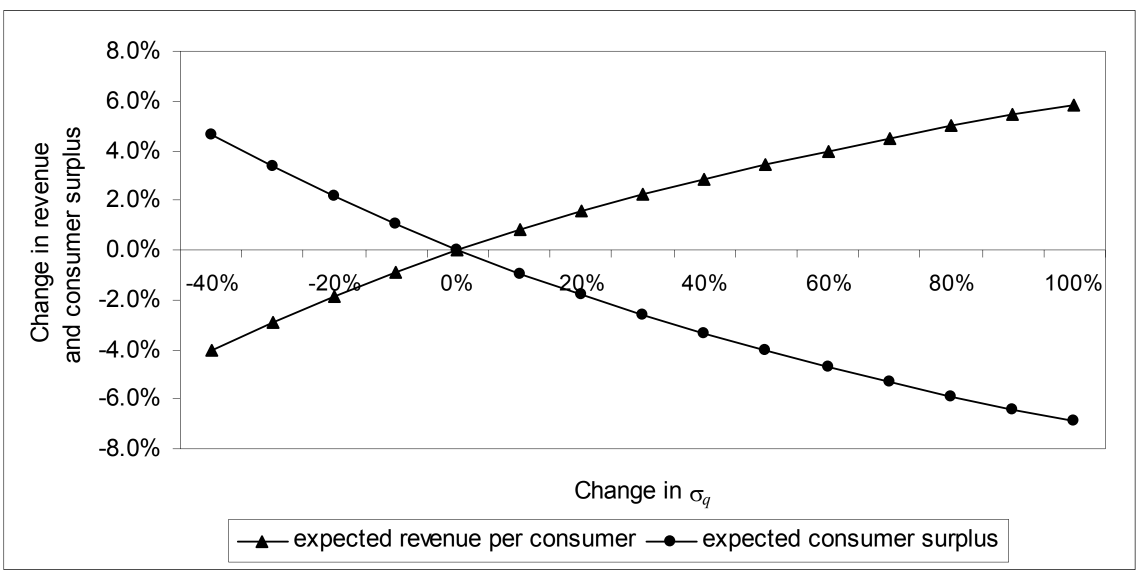


An increase in usage variation, σ_q, thus increases both the probability of choosing a three-part tariff with a higher allowance and the expected bill on a given three-part tariff. This in turn affects provider profit and consumer surplus. Changes in provider profit stem from changes in revenue from consumers with widely fluctuating usage patterns, as well as associated cost considerations. A provider that wants to satisfy maximum demand at all times needs to provide higher network capacity if consumers have highly varying usage. Since the necessary usage capacity depends on correlation and inter- and intra-day fluctuations in individual consumers' usage levels, assessing the profit implications of usage variation is difficult. We focus instead on revenue implications of increasing the standard deviation in usage.

Figure 6 illustrates the relationship between changes in σ_q and provider revenue and consumer surplus. We compute expected consumer surplus and expected provider revenue by numerically integrating over the distribution of the unobserved usage and choice shocks.

We find significant changes in consumer surplus and revenue as consumers' usage variation increases. For example, when usage variation increases by 20%, consumer surplus decreases by 1.8% and revenue increases by 1.5%. 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 at first sight the absolute numbers do not seem large, a windfall revenue gain of 1.5% that might translate into a similar profit increase is very relevant from a provider's perspective. The magnitude of the changes reflects also 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.

Figure 6: Effect of changes in σ_q on provider revenue and consumer surplus



4.3.2 Implications

Our results on consumer demand uncertainty under three-part tariff pricing have implications for both provider and consumer behavior. If consumers have uncertainty over their usage, providers can derive revenues under three-part tariff pricing that they cannot derive under two-part tariff pricing. If the revenue effect is not completely offset by additional costs from providing a higher maximum usage capacity, providers of services where the choice and usage decisions are separated prefer three-part tariff pricing over two-part tariff pricing. In addition, providers have an incentive to target consumers with characteristics that are correlated with high usage fluctuations in order to increase revenue.

Our results show that under three-part tariff pricing usage uncertainty is costly to consumers. A dynamic consideration might then be to smooth out usage over time. Because consumers with high usage variation have a higher expected bill and lower consumer surplus, three-part tariffs are less attractive than two-part tariffs.

5 Conclusion

In this paper, we develop a discrete/continuous model of consumer tariff and usage choices under three-part tariffs. This extends the literature on non-linear pricing that has so far largely focused on two-part tariff pricing. We estimate the model using consumer-level data on Internet usage. In addition, we allow for consumers to leave the current provider and switch to a competitor's tariff. Thus, we make our model applicable to competitive industries. Our results show that demand uncertainty is a key driver of choice between three-part tariffs and steers consumers towards tariffs with high usage allowances. For a given tariff and average usage, the expected bill of a consumer increases with her demand uncertainty and, thus, consumers with high demand uncertainty are more likely to upgrade to a tariff with higher allowance. Consequently, demand uncertainty decreases consumer surplus and, thus, is costly to the consumer. At the same time, providers derive increased revenues from consumers' demand uncertainty that they would likely not earn under two-part tariff pricing.

We also analyze the responsiveness of consumers to the different elements of a three-part tariff. Our findings reveal that for the chosen pricing structure, the access price is the main driver of consumer tariff choice, whose effects dominate any sensitivity to the usage price or the allowance, possibly because the likelihood of exceeding the allowance of a three-part tariff is small. Consequently, a provider's pricing should focus on the access price. We also find that consumers have a preference for flat-rate tariffs.

Our results also allow a more general conclusion. Under two-part tariff pricing providers traditionally discriminate prices based on expected usage. The allowance as an additional element of pricing under three-part tariffs, however, allows providers to set prices that discriminate not only over average usage, but also over variation in usage. Providers can thereby account for consumer uncertainty over usage. One interesting avenue for future research is to further examine price-setting in such two-dimensional non-linear pricing problems and in particular determine optimal intervals between different tariffs' access price and allowance combinations.

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