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In Pursuit of Sustainable Mobile Policy: A Study of Consumer Tariff Preferences under Uncertainty

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Abstract: Literature suggests that consumers expect disutility not only from payment uncertainties but also from reference uncertainties embedded in mobile plans. This paper develops a model of mobile plan choice incorporating both reference and payment uncertainties and uses this model to derive testable implications. The paper argues that consumer choice reflects those uncertainties more than could be justified by rational choice theory. Such patterns, the paper hypothesizes, would be more salient in the choice of data plan than voice plan because consumers tend to perceive data usage to be less controllable than voice usage, thus preferring the plan that reduces uncertainty. The paper tests the predictions with data from a laboratory study analyzing a series of choices between plans with different tariff structures—flat-rate, two-part, and three-part tariffs. As predicted, the results suggest that payment and reference uncertainties create significant disutility for consumers, especially when they perceive high uncertainty about their usage. Such understanding of consumer preference and underlying psychological biases is important in the sense that it provides an essential basis for the development of sustainable mobile policy.

Keywords: tariff structure; reference; uncertainty; gain–loss utility; mobile plans

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1. Introduction

Since the introduction of smartphones to South Korea (hereafter, Korea) in 2009, mobile data (rather than voice calls and text messages) have become central to mobile telecommunications services. (Further, since 2014, voice and text message services have become free peripheral services that are provided with the mobile data service in most mobile plans in Korea.) Most mobile subscription plans since then have adopted a three-part tariff structure: fixed fee, initial usage allowance, and an additional charge for excess usage. Given that the amount of data usage is less salient and perceived to be harder to control (as compared to voice calls and text messages), consumers have welcomed the three-part tariff structure, which renders the total payment to be less volatile. Mobile network operators also prefer three-part tariffs over two-part tariffs, for several reasons. First, with the three-part tariff structure, they have one more component to utilize for optimal pricing. Second, their average revenue stream per user is more stable with the three-part tariff structure, which usually involves charging a higher fixed fee and provides initial usage allowance.

Despite the fact that the three-part tariff structure satisfies both consumers and mobile network operators, it does not seem to result in efficient outcomes for consumers. Although a few studies (e.g., [1,2]) indicate a preference for usage-based tariffs, the majority of previous studies on mobile plan choice (e.g., [3–7]) demonstrate the existence of a preference for flat-rate tariffs or three-part tariffs with higher initial usage allowance over usage-based tariffs. Such preference is observed even when usage-based tariffs are optimal given the consumers' usage patterns. As a result of the suboptimal choices, consumers either overpay for their services (e.g., [8,9]) or increase their usage to deplete their allowance (e.g., [6]).

Consumers are willing to pay more for certainty, potentially driving up their payment as they trade-off "peace of mind" for price. Consumer preference for certainty coupled with mobile network operator's profit-maximizing strategy may cause welfare losses for consumers. In order to encourage more sustainable pricing strategies that do not sacrifice consumer welfare, one must further examine the conditions that influence consumer preference for tariff structures (flat-rate, two-part, and three-part) and the choice of mobile plans.

This study investigates the existence and effects of consumer preference for tariff structures on mobile plan choice via a modified version of the gain–loss utility (GL) model [10,11] and an experimental test of mobile plan choices [12]. The GL model proposes and incorporates reference uncertainty by extending the loss-aversion model based on Kahneman and Tversky [13]'s prospect theory. (There are two models for the expectation-based reference formation: the GL model and the disappointment aversion (DA) model. GL features an endowment effect for risk wherein the risk preferences respond to the stochastic structure of the reference [14]. Unlike the GL model, the use of the DA model varies in the literature. Earlier studies (e.g., [15–17]) propose the certainty equivalent expected utility as a fixed reference. More recent studies build on the notion that agents are sensitive to deviations from the outcome they expect to receive [18,19].) Given the reference uncertainty, a decision maker's preference for uncertain outcomes would reflect both the uncertainties about the amount of consumption (or payment in our case) *and* the reference point. Even though this paper adopts the idea of reference uncertainty to explain consumer preference for the tariff structure of mobile plans, it does not examine the expectation-based reference formation process. (Ever since Kőszegi and Rabin [10], the GL model has been used to endogenize the reference formation as an outcome affected by particular economic environments [20]. The expectation-based reference formation has been the focus of previous theoretical studies (e.g., [11,12,21]). Sprenger [14] and Song [22] also experimentally demonstrate the existence of the formation of the expectation-based reference.) Instead, it focuses on the features of mobile plans that affect consumers' perceived reference and surrounding uncertainty, the tariff structure, and consumers' sense of controllability in their use of mobile telecommunications services.

This paper first hypothesizes that once consumers are given the initial usage allowance in a three-part tariff plan, they stop their reference formation process and regard the initial quota as their status quo or the reference for making a decision. Suppose that the (dis)utility from payments bears a property where the excess usage over the reference, which can either be stochastic or not, is regarded as a loss. Thus, the paper predicts that the three-part tariff structure would effectively eliminate the reference uncertainty. Similarly, flat-rate tariffs effectively remove both payment and reference uncertainties, while two-part tariffs do neither. Overall, the preference for the three-part tariffs over the two-part tariffs is expected to be more prominent if consumers are influenced by reference uncertainty.

This paper also hypothesizes that the perceived controllability of consumers is related not only to the payment uncertainty but also to reference uncertainty, (Empirical and theoretical research on decision making under risk has long identified the perception of uncertainty and lack of control as central determinants of risk perception in lay people [23–25].) which, in turn, affects consumers' preference for tariff structure. Regarding voice usage, all mobile telecommunications network operators in Korea count and charge usage for callers only. Meanwhile, those in the US count and charge calls from both callers and recipients. Thus, Korean mobile (voice) users can more closely control their metered usage than US users. Moreover, they are likely to have a lower degree of reference uncertainty. (The difference stems from the different payment models: only callers pay for their calls (calling party pays) in Korea while both callers and recipients pay (receiving-calling party pays) in the US. We also use the difference as a source in a different sense of control among consumers, which plays a significant role in this study.) It is unlikely to be a coincidence that most of the mobile plans followed the three-part tariff structure from the early era of mobile telecommunications services in the US, while the "standard" plans in Korea adopted the two-part structure. Regarding data usage, however, consumers' perceived controllability is lower. For example, smart-device users keep receiving push messages, which consume data without any active use of mobile devices. It is also challenging to correctly recognize the amount of data used as compared to voice usage, leading the users to feel greater reference and payment uncertainty. Thus, the paper predicts that consumers' preference for the three-part tariff over the two-part tariff will be more pronounced under data usage than under voice usage.

This paper employs a laboratory experiment to test the hypotheses driven by our model. Our design exploits the notion that only payment uncertainty affects the utility of consumers subscribing to three-part tariff plans, while both the payment (or equivalently usage in this case) and reference uncertainty affect the utility of consumers subscribing to two-part tariff plans. In the first half of the experiment, subjects report their usage behaviors under voice and data services. Based on a combination of the subjects' responses and information obtained from a network operator (average monthly usage and the proportion and amount of excessive usage, (We obtained the information from a major mobile telecommunications network operator in Korea, via the Korea Communications Commission. The related information covers all third- and fourth-generation (3G and 4G, respectively) mobile plans (see the Appendix A: Tables A1 and A2), but it does not cover the rest of the plans, which very few subjects chose.) for the mobile plan), the program conjectures the subjects' usage distribution. In the second half of the experiment, based on the conjecture, the program creates an individualized usage distribution of voice and data services for each subject and generates flat-rate, two-part, and three-part tariffs with differing expected payments for both services.The program collects each subject's preferences via a multi-round of preferred plan choice, where subjects are required to compare a pair of mobile plans and select a preferred one in each round. The expected payments are either the same, 10% different, or 20% different for a pair. Thus, the research attempts to identify the existence and degree of consumer preference for tariff structures.

The results show that subjects prefer flat-rate tariffs over three-part tariffs, and three-part tariffs over two-part tariffs, in that order. The observed preference is stronger under data usage than under voice usage. The paper finds that subjects' preference for flat-rate tariffs over three-part tariffs is relatively weaker, especially under voice usage. This implies that reference uncertainty is a greater source of disutility than usage uncertainty for consumers. Similarly, the preference for three-part tariffs is more pronounced under data usage. This contrast is consistent with our predictions and is driven by the difference in the consumers' perception of the sense of controllability under voice and data usage.

The current study stems from prior studies on mobile plans and tariffs such as Bar-Gill and Stone [26] and Herweg and Mierendorff [27]. They note that the actual payment volatility is not high enough to be justified with the rationality approach, thus increasing the need to adopt a behavioral economics approach. While there is no single, widely accepted model of reference formation, many previous studies agree that initial endowments play such a role in a loss-aversion model (e.g., [28,29]). Herweg and Mierendorff [27] demonstrate in their theoretical analysis that, when consumers are loss-averse and uncertain about their future demand, they may prefer a flat-rate payment over a measured tariff before learning their preferences despite the higher expected consumption with the measured tariff. Leider and Şahin [7] show theoretically and experimentally that consumption is affected by the tariff structure (pay-per-use vs. three-part tariffs). Note that they focus their theoretical and experimental analyses on usage. The current study, for the first time in the literature (to the best of our knowledge), (There are a couple of recent studies addressing the effect of consumer preference on tariff choice in other context than mobile plan choice. Dowling et al. [30] examined the effect of overconfidence in the choice between a pay-per-use and a flat-rate option using an experimental approach and found that overconfident consumers choose a flat-rate option more frequently than underconfident consumers. Dowling et al. [31] demonstrated the existence and persistence of the pay-per-use bias in a new- car-sharing -context.) addresses the effect of consumer preference for tariff structures on mobile plan choice using both theoretical and empirical approach.

South Korea's telecommunications market is highly competitive and saturated. In addition, the telecommunications industry is regulated; the entry and exit have to be authorized, and regulations on fees still exist. In particular, mobile telecommunications user fees are the subject of the public policy closely related to our daily lives. (Recently, as an example, a specific telecommunications company tried to provide an exceptionally inexpensive mobile plan, but the government did not permit it under policy judgment [32].) As with other regulated industries (i.e., the energy industry), the public policy in telecommunications pricing aims to ensure that companies can sustainably provide high-quality telecommunications services without making excessive profits. The mobile telecommunications industry, however, is unique in that it has a high fixed cost and a low marginal cost, which allows more variations in devising tariff plans compared to other utility industries such as energy, where the focus is on rate-making. Thus, a deep understanding of consumer preferences and biases is crucial in order to structure sustainable tariff plans.

This paper examines the process of consumers choosing tariff plans from a behavioral economic point of view. Through an experiment, we analyzed the characteristics of consumers' actual choices. We believe that an improved understanding of consumers' behavior in the wild will contribute to suggesting a pricing strategy that will enhance both consumer welfare and the sustainable mobile telecommunications industry. The rest of this paper proceeds as follows. Section 2 describes the model. Section 3 describes an experiment to test the hypotheses derived from the model. Section 4 presents the results and discussion. Section 5 concludes.

2. Model

The traditional rational approach, the expected utility theory has some limitations in explaining consumers' behavior and related public policy for mobile plans. In this section, we construct a model from the perspective of a behavioral economics by allowing payment and reference uncertainties. Understanding and modeling consumer choice is necessary to derive pricing policy for sustainability. A loss-averse consumer's utility is represented as $u(c|r) = m(c) + n(c|r)$ where $m(c)$ is an intrinsic utility from consumption c, r is the reference around which the loss aversion occurs, and $n(c|r)$ is the loss-aversion utility, which satisfies the properties of Kahneman and Tversky [13]'s loss-aversion utility model. (Kőszegi and Rabin [10] adopt the first-order risk-averse approach and represent the loss-averse utility function $n(c|r)$ as $\mu(c - r)$ where $\mu(\cdot)$ is increasing, $\mu(-\delta) < 0 < \mu(\delta)$ and $|\mu(-\delta)| > \mu(\delta)$ for any $\delta > 0$.) Note that r is not necessarily deterministic, which is the key feature of the GL model.

Given the probability density function of consumption and reference point ($f(c)$ and $g(r)$, respectively), we assume that an outcome is evaluated according to its expected utility, with the utility of each outcome being the average feeling relative to each possible realization of the reference. Thus, the expected utility can be expressed as follows:

$$EU(c,r) = \int\int u(c|r)g(r)f(c)drdc.$$

We then modify the GL model to represent a consumer's expected utility from payments for usage q with their mobile plan as follows:

$$\int\int l(p(q)|r)g(r)f(p(q))drdq$$

where $p(q)$ is the amount of payment from the usage, and $l(\cdot)$ represents the disutility from payment. Note that with abuse of the notation, the reference r now indicates the consumer's payment (not usage), although the amount of payment $p(q)$ and the amount of usage q is closely related. The payment uncertainty can be low even though the usage uncertainty is high. However, if the payment uncertainty is high, the usage uncertainty must be high. We also assume that the consumer's reference-dependent utility from payment is symmetric in both directions. That is, unlike the typical loss-aversion model, consumers dislike not only overpaying but also underusing the initial usage allowance of their mobile plan. Our assumptions imply that a consumer's value of a mobile service primarily stems from their subscription to a mobile service rather than the amount of service consumed.

We predict that the three-part tariff structure, which includes an initial endowment of uncharged usage, would create a reference point for consumers. Moreover, the flat-rate structure removes both uncertainties, and the two-part tariff structure removes none.

Conjecture 1. *The initial usage endowment (e.g., "free" minutes or bytes) in the three-part tariff structure, which is regarded as the reference, removes consumers' uncertainty about the reference.*

Our conjecture is based on major mobile subscription plans in Korea since 2010, which explicitly express the size of fixed fees, such as "LTE 42" (KRW 42,000) and "3G 54" (KRW 54,000).

The following subsections build a simple model to explain how each tariff structure differently reflects the disutility from payment and reference uncertainties. We assume that the benefit from mobile telecommunications services is sufficiently high and the same for all users. Thus, we can focus only on the disutility difference from payments.

2.1. Payment Uncertainty

This subsection focuses on the disutility from payment uncertainty without considering the uncertainty in the reference; that is, r is deterministic. Note that the disutility from the payment uncertainty itself is a rational property: a risk-averse rational agent does not like fluctuations in the outcome. However, it becomes a behavioral assumption once we start to consider the disutility from not only the uncertainty in the payment amount, as reflected in the variance, but also the deviation from the reference.

2.1.1. Two-Part Tariff

The two-part tariff plan can be represented as (α_2, β), where α_2 is the fixed fee and β is the marginal rate (per minute or kilobyte, for example). Thus, to reflect reality, we let the marginal rate β be the same for all cases. (It is 1.8 KRW per second for voice, which is approximately USD 0.1 per minute, and 12.5 KRW per megabyte for data.) Let q_r be the amount of usage that exactly meets the reference payment r, which is represented as $r = \alpha_2 + \beta q_r$. Suppose, for simplicity, that the disutility from the deviation from the reference payment is quadratic. Thus, given a two-part tariff plan, the expected disutility is represented as follows:

$$l(r, p_2(q)) = \int_0^\theta \gamma[\alpha_2 + \beta q - (\alpha_2 + \beta q_r)]^2 f(q;\theta) dq \tag{1}$$

where $p_2(q)$ is the payment under the two-part tariff plan for usage q, γ is a positive constant, and θ is the maximum possible usage. Moreover, for simplicity, suppose that the probability density function $f(\cdot)$ is a continuous uniform distribution with the maximum possible usage being the upper bound, $f(q;\theta) = 1/\theta$. Then, Equation (1) is rewritten as follows:

$$\begin{aligned} l(r, p_2(q)) &= \gamma \int_0^\theta \beta^2 (q - q_r)^2/\theta dq \\ &= \gamma\beta^2(\theta^2 - 3\theta q_r + 3q_r^2)/3. \end{aligned}$$

Following the assumption of the rational expectation quantity as the reference [10], let $q_r = \theta/2$ be usage at the reference. Thus, the disutility can be simplified as

$$l(r, p_2(q)) = \gamma(\beta\theta)^2/12, \tag{2}$$

with the expected payment of

$$E_q[p_2(q)] = \alpha_2 + \beta\theta/2. \tag{3}$$

2.1.2. Three-Part Tariff: Case 1 ($p_3(\tilde{q}) < r$)

A three-part tariff plan is composed of flat rate α_3, initial usage allowance $\tilde{q}$, and the rate for excess usage β. Compared with the two-part tariff, we have one more component: initial usage allowance.

In Case 1, users consume more than the initial allowance offered by their mobile plan. That is, the payment from using up the initial usage allowance, $p_3(\tilde{q})$, is supposed to be lower than the payment reference r, thus implying that the user is likely to use more than $\tilde{q}$. Hence, $\tilde{q} < q_r$, where q_r satisfies $p_3(q_r) = \alpha_3 + \beta(q_r - \tilde{q}) = r$.

The disutility from payment uncertainty, which arises when q becomes greater than $\tilde{q}$, is represented as follows:

$$\begin{aligned} l(r, p_3(q)) &= \int_{\tilde{q}}^{\theta} \gamma[\alpha_3 + \beta(q - \tilde{q}) - (\alpha_3 + \beta(q_r - \tilde{q}))]^2/\theta dq \\ &= \gamma\beta^2/(3\theta)[(\theta - q_r)^3 - (\tilde{q} - q_r)^3]. \end{aligned}$$

Under the assumption of the rational expectation reference, $q_r = \theta/2$. Moreover, the disutility is rewritten as

$$\begin{aligned} l(r, p_3(q)) &= \gamma\beta^2/(3\theta)[(\theta/2)^3 - (\tilde{q} - \theta/2)^3] \\ &= \gamma\beta^2/(3\theta)(\theta - \tilde{q})(\tilde{q}^2 - \theta\tilde{q}/2 + \theta^2/4), \end{aligned} \tag{4}$$

and the expected payment is

$$\begin{aligned} E_q[p_3(q)] &= \int_0^{\tilde{q}} \alpha_3/\theta dq + \int_{\tilde{q}}^{\theta} (\alpha_3 + \beta(q - \tilde{q}))/\theta dq \\ &= \alpha_3 + \beta(\theta - \tilde{q})^2/(2\theta). \end{aligned} \tag{5}$$

2.1.3. Three-Part Tariff: Case 2 ($p_3(\tilde{q}) \geq r$)

In Case 2, users leave unused minutes initially allotted under their mobile plans. That is, the payment from using up the initial usage allowance, which is α_3, is now greater than the payment reference r, implying that the user is likely to use less than $\tilde{q}$. Thus, $\tilde{q} \geq q_r$, and $p(q_r) = \alpha_3$. The disutility is now

$$\begin{aligned} l(r, p_3(q)) &= \int_{\tilde{q}}^{\theta} \gamma[\alpha_3 + \beta(q - \tilde{q}) - \alpha_3]^2/\theta dq \\ &= \gamma\beta^2(\theta - \tilde{q})^3/(3\theta). \end{aligned} \tag{6}$$

Note that the functional representation of the expected payment in Case 2 is the same as Equation (5).

2.1.4. Comparison

We now compare the two cases of the three-part tariff. Thus, to examine the difference in disutilities from the different tariff structures, let the two expected payments from Case 1 and Case 2 be the same, or

$$\alpha_{31} + \beta(\theta - \tilde{q}_1)^2/(2\theta) = \alpha_{32} + \beta(\theta - \tilde{q}_2)^2/(2\theta),$$

where α_{31} and $\tilde{q}_1$ refer to the fixed fee and the initial allowance, respectively, in Case 1, and α_{32} and $\tilde{q}_2$ function similarly in Case 2. Without considering the disutility from payment uncertainty, a rational and risk-neutral user must feel indifferent between these two plans.

The disutility in Case 1 is $l_1 = \gamma\beta^2/(3\theta)\left[(\theta/2)^3 - (\tilde{q}_1 - \theta/2)^3\right]$, while the disutility in Case 2 is $l_2 = \gamma\beta^2/(3\theta)(\theta - \tilde{q}_2)^3$. Thus, the difference, $l_1 - l_2$, is

$$l_1 - l_2 = \gamma\beta^2/(3\theta)[(\theta/2)^3 - (\tilde{q}_1 - \theta/2)^3 - (\theta - \tilde{q}_2)^3].$$

Proposition 1. *Given the same expected payments, the disutility from Case 1 of three-part tariff is greater than that from Case 2, or $l_1 - l_2 > 0$.*

Proof. Given $\tilde{q}_1 < \theta/2$ and $\tilde{q}_2 > \theta/2$, we know that $l_1 - l_2$ would be minimized at $\tilde{q}_1 = \theta/2$ and $\tilde{q}_2 = \theta/2$, which leads to $l_1 - l_2 = 0$. Thus, $l_1 - l_2$ must be greater than zero. □

Note that the two-part tariff is a specific case of three-part tariff in Case 1 where $\tilde{q}_1$ is zero, and flat-rate tariff is another specific case of the three-part tariff in Case 2 where $\tilde{q}_1 \geq \theta$. We can conclude that given the same expected payment, the lower the amount of initial allowance, the bigger the disutility from payment uncertainty. Based on Conjecture 1 and Proposition 1, we propose the following hypothesis:

Hypothesis 1 (H1). *Given the same expected payment, users prefer flat-rate tariffs over three-part tariffs and three-part tariffs over two-part tariffs.*

Hypothesis 1, if true, explains why consumers prefer mobile plans with a high fixed fee and a large amount of initial allowance. It is also a property that mobile network operators can exploit to increase their profits by tweaking the fixed fee amount and initial allowance of mobile plans.

2.2. Reference Uncertainty and Sense of Controllability

We now examine the case where consumers have uncertainty in the reference as well, and represent the consumer's disutility as

$$l(r, p_j(q)) = \int \gamma(p_j(q) - r)^2 f(q;\theta)g(r;\theta)dqdr, \tag{7}$$

where $g(r;\theta)$ is, with abuse of notation, the distribution (or belief) of a consumer's reference payment r.

Thus, given a two-part tariff plan (α_2, β), $l(r, p_j(q))$ is represented as

$$l(q_r, p_j(q)) = \int \gamma\beta_2^2/3(\theta^2 - 3\theta q_r + 3q_r^2)h_2(q_r;\theta)dq_r,$$

where $h_2(q_r;\theta)$ is the distribution of the usage derived from $r = \alpha_2 + \beta q_r$ and $g(r;\theta)$ for the two-part tariff plan. The support of $h_2(q_r;\theta)$ should be equal to or a subset of the support of $f(q;\theta)$. Suppose, for simplicity, that $h_2(q_r;\theta)$ is the same as $f(q;\theta) = 1/\theta$. Then, the disutility is

$$l(q_r, p_j(q)) = \gamma(\beta\theta)^2/6, \tag{8}$$

which is twice the value of Equation (2). In contrast, given a three-part tariff plan, consumers have the same disutility as that in Case 1 as long as the initial usage allowance dissipates the uncertainty around the reference.

Common risk assessments are made more intuitively than analytically [33,34] based on how uncertain a situation appears to be and how much control one feels in the situation. It is well-known that the sense of controllability is related to perceived risk: the more uncertainty one perceives, the less control one perceives in the situation, and thus the higher the risk assessment. For voice calls, almost all mobile plans in Korea count and charge usage only for the caller, whereas both caller and recipient minutes (although usually in the daytime) are counted and charged in the US. Thus, Korean mobile users can more closely control their metered usage of voice calls than US users. Moreover, they are likely to have a lower degree of reference uncertainty under voice usage. The sense of controllability, however, is not applicable to data usage. For example, smart-device users keep receiving push messages as long as their devices are connected to the Internet, regardless of their active device usage. Thus, they may feel a relatively greater reference uncertainty in their data usage.

This study assumes that the sense of controllability and estimate of usage are related. A more accurate estimate of usage, or a lower usage uncertainty, implies a greater sense of controllability and vice versa, which leads to the following hypothesis.

Hypothesis 2 (H2). *Consumers' estimates of voice usage are likely to be more accurate than those of data usage.*

Finally, we hypothesize that in addition to the usage uncertainty, the sense of controllability exerts an influence on consumers' perception of the reference uncertainty.

Hypothesis 3 (H3). *The consumer's preference for three-part tariffs over two-part tariffs will be more pronounced under data usage than voice.*

If Hypothesis 3 is true, consumers' disutility from reference uncertainty under data usage is greater than that under voice usage. That is, the (normalized) variance of their (subjective) probability distribution of the reference for data usage is greater than that for voice.

2.3. The Effect of the Amount of Fixed-Fee on Tariff Preference

Note that Equations (2) and (8) include no fixed-fee component (α) and are affected only by the uncertainty-related term (β). If these equations are indeed consistent with the consumers' behavior, the amount of fixed-fee and, thus, the change in the amount of expected payment would not alter both the disutility from payment uncertainty and that from reference uncertainty. This leads to the following hypothesis.

Hypothesis 4 (H4). *The amount of fixed fee and/or the expected payment do not affect consumers' preference for tariff structures.*

Hypothesis 4 implies that, for example, if a consumer prefer a three-part tariff plan to flat-rate tariff one, the consumer must prefer a three-part tariff to flat-rate tariff for any level of fixed fee as long as the payment uncertainty/varying part in each tariff structure does not change (i.e., preference consistency).

3. Experiment

The experiment seeks to find evidence for the differential effect of payment and reference uncertainty in consumers' actual choice of voice versus data plan with the overarching goal of providing descriptive bases for sustainable pricing policy. Specifically, the experiment was designed to identify (i) the disutility from payment uncertainty, (ii) the disutility from reference uncertainty, and (iii) whether the disutilities captured from (i) and (ii) are similar in both voice and data usage. (To implement this experiment, a Visual Basic script in the MS Excel program was used.)

The experiment proceeded in two parts. In the first half, subjects responded to a series of questions about their experience with mobile telecommunications services. Specifically, they reported on their current mobile plan, their estimation of monthly expenses, and whether (and how many times) they experienced excess usage of minutes (voice) or megabytes (data) and extra payment in the last six months. Given the subjects' responses and the information on their subscription plan, (It includes the average usage, the proportion of subscribers with excess usage, and the amounts of excess usage for each of the major mobile plans from a major mobile network operator in Korea. We greatly appreciate their courtesy for providing the data.) we projected and generated distributions of an individual subject's voice and data usage pattern. In the second half, subjects were asked to make a series of choices between 14 pairs of subscriptions plans, which were dynamically generated with the individual subject's usage distributions derived in the first stage of the experiment. The pairs included flat-rate, two-part, and three-part tariffs. Finally, subjects were asked to check and submit their actual usage information for the past three or more months from their mobile telecommunications service providers' webpage or its smartphone application, with extra compensation (KRW 2000, approximately USD 2).

This approach was chosen to encourage subjects to make decisions in a realistic manner. (We pose the question of whether our distribution conjecture, as compared to a subject's guess, is (1) mostly correct, (2) somehow correct, (3) somehow wrong, or (4) mostly wrong. For voice usage, 61.90%, 21.43%, 11.90%, and 4.76% of the subjects answered 1 to 4, respectively; thus, 83% of the answers are positive. For data usage, 16.67%, 54.76%, 23.81%, and 4.76% of the subjects answered 1 to 4, respectively; thus, 72% of the answers are positive. We believe that the difference in subjects' evaluation between voice and data usage is related to the accuracy of their estimates of voice and data usage, as stated in Section 4.3.) An alternative approach of presenting hypothetical usage tables to subjects and asking them to choose a plan therein would likely induce a rational behavior; the tables and numbers would encourage computational rather than conjectural choices.

3.1. Material and Methods

3.1.1. Assessment of Subjects' Usage Distributions

A triangular distribution of usage X was used to assess a subject's usage distribution. The triangular distribution has the following three parameters: $X_{\max}$, $X_{\min}$, and $\bar{X}$ where $\bar{X}$ is the mean. (Although, using a triangular distribution is not common, we choose this approach for a specific reason. The Solver in MS Excel sometimes fails to produce results by minimizing root-mean-square (RMS) errors in the middle of experiments when we use log-normal or other long-tailed, two-parameter probability distributions.) The conjecture of a subject's usage distribution determines the values of these parameters based on a subject's responses and the following information of each subscription plan that the subject chooses from actual data: average monthly usage ($\bar{X}^{market}$), initial allowance (X_u), and the probability of overuse ($\Pr^{market} = \Pr(X > X_u)$), based on the proportion of overuse data.

For each subject, the usage distribution is initially generated according to the current mobile plan. Subsequently, the distribution is tweaked based on the subject's answers for his/her experience of using (i.e., over- and underusing) the mobile telecommunications service for the past six months. A subject's probability of overuse $P_R = \Pr(X) > X_u$ is obtained from the subject's responses about usage. We use the minimization of RMS errors to determine the value of $\bar{X}$, $X_{\max}$ and $X_{\min}$, thus reflecting the conditions stated above. (By minimizing the RMS Errors, $\sqrt{\left(\frac{\bar{X}^{market} - \bar{X}(X_{\min}, X_{\max})}{\bar{X}^{market}}\right)^2 + \left(\frac{\Pr^{market} - P_R(X_{\min}, X_{\max})}{\Pr^{market}}\right)^2}$, the shape of subjects' usage distribution is as close as possible to their groups that use the same subscription plan. Moreover, note that a primary objective of our experiment is to make the subjects "feel" like their choices are based on their own perception of usage, not on a statistically flawless distribution. About 70% of subjects reply that our conjectures of their usage distributions are similar to their actual usage patterns.)

After the assessment of each subject's usage distribution, we determine the expected payment for each subject and use it as the base level of payment.

3.1.2. Choice of a Preferred Plan

In the second half of the experiment, each subject is asked to compare two plans and choose one. Questions about voice and data usage are separated. Based on the usage distribution assessment, two flat-rate, two two-part tariff, and three three-part tariff plans with different expected payments are generated for our analysis. Table 1 shows the generated plans used for the discrete choice experiment regarding expected payments and tariff structures. Superscripts are used to index a specific plan with the same tariff structure.

Table 1. Tariffs and plans for subjects.

Expected Payment Level	Two-Part Tariff (2PT)	Three-Part Tariff (3PT)	Flat-Rate Tariff (FT)
base + 20%			FT^2
base + 10%		3PT^2	
base	2PT^1	3PT^1	FT^1
base − 10%		3PT^3	
base − 20%	2PT^2		

The metered rate for voice, if applicable, is defined to be KRW 108 (approximately USD 0.1) per minute, which reflects the current practice. The data rate is set to be KRW 12.5 per megabyte (MB). (The voice rate is KRW 1.8 per second in almost all available plans in Korea in 2012. Unlike voice calls, data rates vary among major plans. We use the rates of major 3G mobile plans in 2012 (see the Appendix A: Tables A1 and A2).) For three-part tariff plans, the amount of initial allowance, X_u needs to be determined. At the base level, the amount is determined such that the chance of excess usage is 25%, or $\Pr(X > X_u) = 0.25$. At the $+10\%$ base level, the chance is 15%, and it is 35% at the -10% base level. The two-part tariff and flat-rate tariff plans are differentiated by a 20% difference in the expected payment to capture the subjects' willingness to avoid (or take) the payment uncertainty. Finally, the fixed fee of the two-part tariff plan at the -20% base level is adjusted such that the expected payment becomes 20% lower than the case of the two-part tariff plan at the base level. The maximum decrease in the fixed fee is set to KRW 10,000 to avoid the possibility that the fixed fee is too low (e.g., less than KRW 1000) for a subject who pays a minimal amount for mobile telecommunications services. All numbers related to payments are rounded at KRW 1000.

A subject is supposed to choose the preferred tariff from a pair of plans with different tariff structures. Given the set of plans in Table 1, 16 questions are required for a comprehensive analysis. However, we drop the comparisons between 2PT^1 and 3PT^3, as well as 3PT^2 and FT^1 where, in both cases, the first plan is strictly worse than the second one regarding both the expected payment and payment uncertainty. Overall, a subject is asked two sets (voice and data) of 14 questions in the second half of the experiment.

A mobile plan was modeled as a function of usage. (In 2012, most Korean mobile telecommunications service plans did not include unlimited or discounted voice usage. An unlimited data option for 3G (not long-term evolution; LTE) data was provided in upper-tier plans (see the Appendix A: Tables A1 and A2).) Table 2 shows the equations used for tariff structures in the experiment. The numbers are matched with the superscript of the plans in Table 1.

Table 2. Equations for tariffs generation.

No.	Two-Part Tariff	Three-Part Tariff	Flat-Rate Tariff
1	$a_2^1 + 108X$	$\begin{cases} a_3^1 & (\text{if } X \le X_u^1) \\ a_3^1 + 108(X - X_u^1) & (\text{otherwise}) \end{cases}$ $\Pr(X > X_u^1) = 25\%$	a_1^1
2	$a_2^2 + 108X$	$\begin{cases} a_3^2 & (\text{if } X \le X_u^2) \\ a_3^2 + 108(X - X_u^2) & (\text{otherwise}) \end{cases}$ $\Pr(X > X_u^2) = 15\%$	$a_1^2\ (= 1.2a_1^1)$
3		$\begin{cases} a_3^3 & (\text{if } X \le X_u^3) \\ a_3^3 + 108(X - X_u^3) & (\text{otherwise}) \end{cases}$ $\Pr(X > X_u^3) = 35\%$	

a_1^1 is drawn from a respondent's choice of subscription plan; a_2^1 and a_3^1 are determined to satisfy $E[\text{2PT}^1(X)] = E[\text{3PT}^1(X)] = E[\text{FT}^1]$.

3.2. Subjects

The experiment was conducted at a major University in Seoul, Korea. The subjects were recruited with an advertisement at the department administrative offices of the university. Subjects were rewarded a gift certificate of KRW 5000 and an additional KRW 2000 upon providing their actual usage information at the end of the experiment, which we did not inform them in advance to prevent subjects from getting "correct" information about their usage before the experiment. Overall, 312 subjects participated, mostly students between the ages of 20 and 24. Most of them (96.7%) subscribed to a mobile plan for smartphones; this percentage was much greater than the smartphone penetration rate in Korea at the time of the experiment (67.6%). Of them, 40.38% subscribed to SK Telecom, 42.31% to KT, and 17.31% to LGU+. (We clarify that these names are official ones, not abbreviations.) This distribution seems to be significantly different from the mobile telecommunications market shares in Korea: 50% (SKT), 30% (KT), and 20% (LGU+). However, considering the higher proportion of smartphone use among the participants, and the market share of 3G and 4G mobile telecommunications services, (For 3G mobile telecommunications services in Korea, the market shares of KT and SKT are approximately equal, while LGU+ does not provide a 3G service. In contrast, KT discontinued their second-generation (2G) mobile service from 2011. Most smartphones since then do not function properly on 2G mobile networks. For 4G (LTE) telecommunications services, which were first launched at the end of 2011, the shares are again 50% (SKT), 30% (KT), and 20% (LGU+), as of the third quarter of 2012.) The distribution of service providers is not significantly different from the market shares of smartphone users in Korea.

About 80% (248) of them submitted their actual usage amount for the past three to six months. The average voice usage estimate is 168.78 min per month, with a standard deviation of 153.44. The average voice usage is 174.65 min per month, with a standard deviation of 146.90. The average data usage estimate is 1.684 gigabytes (GB) per month, with the standard deviation of 2.503. The average data usage is 2.294 GB per month, with a standard deviation of 2.342. The summary statistics above are evaluated after dropping 12 samples (about 5%), which are mostly extreme outliers.

Subjects' awareness of their subscription plan is summarized as follows: 8.33% of subjects report that they have no idea about their monthly payments, 32.69% report they have some estimation of their monthly payment, 24.36% report they know the basic allowance of their plan, and 34.62% report that they are aware of the overall tariff structure of their plans. Subjects estimate that their average monthly payment is 59,200 KRW, with a standard deviation of 17,700 KRW.

4. Results

Let the null hypothesis be that subjects are indifferent between any pair of tariff structures, which implies that the proportions of subjects between the two plans would be 50:50. (Since our measurements are binary, the null hypothesis is binomially distributed with the following parameters: $n = 312$ and $p = 0.5$. Since n is large, we can approximate the distribution with a normal distribution having a mean of 156 ($312 \times 0.5 = 156$) and a standard deviation of 8.83($\sqrt{312 \times 0.5 \times 0.5} = 8.83$). Our critical value for the 5% significance level is 1.96.) The hypotheses were tested with a z-test, $z = (X - \mu)/\sigma$, where μ is the mean at 156, and σ is the standard deviation at 8.83.

Overall, the subjects' choices between the pairs of plans reveal the following. (i) They seem to be indifferent between the flat-rate and the three-part tariff in voice usage, but they prefer the flat-rate over the three-part tariff in data usage. (ii) They prefer the three-part tariffs over the two-part tariffs in both types of usage. This phenomenon is, nonetheless, more pronounced in data usage. (iii) They prefer the flat-rate tariff over the two-part tariff. Table 3 (Voice) and Table 4 (Data) present results of the subjects' preference between the two plans.

To formally test the statistical significance of subjects' preference for tariff structures between data and voice usage, we run a logistic regression, using the choice of the second option plan as a dependent variable and data usage as an independent dummy variable. The results are presented in Table 5.

4.1. Voice Usage

Overall, the results provide partial support for Hypothesis 1 and generally reject Hypothesis 4.

4.1.1. Flat-Rate vs. Three-Part Tariffs

At the base level, where the expected payments are the same, we find that subjects are completely indifferent between the flat-rate tariff (FT^1) and the three-part tariff ($3PT^1$) ($z = 0$, $p = 1$). When the expected payment for a flat-rate tariff plan is 20% higher (FT^2), and that for a three-part tariff plan is 10% higher ($3PT^2$), subjects prefer the three-part tariff over the flat-rate tariff (72.76%, $z = 8.041$, $p < 0.001$) , which is significantly different from the preference observed at the base level. Between the flat-rate tariff plan at the base level (FT^1) and the three-part tariff plan with a 10% lower expected payment than the base ($3PT^3$), subjects prefer the three-part tariff over the flat-rate tariff (70.83%, $z = 7.361$, $p < 0.001$). Consistent with Hypothesis 4, it appears that the amount of fixed fee and/or the expected payment do not affect subjects' preference.

4.1.2. Flat-Rate vs. Two-Part Tariffs

At the base level, where the expected payments are the same, we find that subjects prefer the flat-rate tariff(FT^1) to the two-part tariff plan ($2PT^1$) (56.41%, $z = 2.26$, $p = 0.024$). When the expected payment for a flat-rate tariff plan is 20% higher (FT^2) than the base level, subjects' preference reverses and they prefer the two-part tariff ($2PT^1$) to the flat-rate tariff (FT^2)(78.53%, $z = -10.08$, $p < 0.001$). When the expected payment is 20% lower for a two-part tariff plan ($2PT^2$), subjects prefer the two-part tariff plan ($2PT^2$) over the flat-rate tariff plan at the base level (FT^1) (58.65%, $z = -3.058$, $p = 0.002$).

Note that in both cases, the expected payment for a flat-rate tariff plan is about 20% higher than that for a two-part tariff plan. Comparing the decreases in the proportion of subjects who choose a flat-rate plan, 35% and 15% in the high and low expected payment cases, respectively, we can conclude that Hypothesis 4 is rejected.

4.1.3. Three-Part vs. Two-Part Tariffs

Here again at the base level, where the expected payments are the same, we find that subjects prefer the three-part tariff plan ($3PT^1$) over the two-part tariff plan ($2PT^1$) (58.65%, $z = 3.058$, $p = 0.002$). When the expected payment for a three-part tariff plan increases by 10% from the base level ($3PT^2$), subjects prefers the two-part tariff plan at the base level ($2PT^1$) over the three-part tariff plan ($3PT^2$) (63.46%, $z = -4.757$, $p < 0.001$), which is a reversal of preference from the comparison of plans at the base level ($3PT^1$ vs. $2PT^1$). When the expected payment with three-part tariff decreases by 10% from the base level ($3PT^3$), and the expected payment with two-part tariff decreases by 20% from the base level ($2PT^2$), subjects prefer the three-part tariff ($3PT^3$) over the two-part tariff ($2PT^2$) (58.65%, $z = 3.058$, $p = 0.002$), which matches the preference observed in the comparison of plans at the base level.

In both cases, the expected payment for a three-part tariff plan is about 10% higher than that for a two-part tariff plan. Comparing the decreases in the proportion of subjects who chose three-part tariff plans (22% and zero, respectively), Hypothesis 4 is again rejected.

4.2. Data Usage

The results provide strong evidence in support of Hypotheses 1 and 3. Overall, the subjects seem to be more consistently inclined to avoid uncertainty in data usage than in voice.

4.2.1. Flat-Rate vs. Three-Part Tariffs

At the base level, where the expected payments are the same, subjects prefer a flat-rate tariff plan (FT^1) over a three-part tariff plan ($3PT^1$) (56.41%, $z = -2.265$, $p = 0.024$), which is different from the indifference observed in the voice plan choice. The difference in the preference between the voice plan and the data plan is marginally significant ($p = 0.109$) when tested with the logistic (probit) regression at the 5% significance level.

When the expected payment for a flat-rate tariff plan increases by 20% from the base level (FT^2) and that for a three-part tariff plan increases by 10% ($3PT^2$), subjects prefer the three-part tariff ($3PT^2$) over the flat-rate tariff(FT^2) (58.01%, $z = 2.831$, $p = 0.005$). This preference, although consistent in direction, is significantly less pronounced in the data plan choice than in the voice plan choice ($z = 3.85$, $p < 0.001$)

When the expected payment for a three-part tariff decreases by 10% ($3PT^3$) and is paired with the flat-rate tariff plan at the base level (FT^1), subjects prefer the three-part tariff plan over the flat-rate tariff plan (56.41%,$z = 2.265$, $p = 0.024$). This preference, although consistent in direction, is significantly less pronounced in the data plan choice than in the voice plan choice ($z = 3.73$, $p < 0.001$). As in the voice usage case, it is hard to conclude that the amount of fixed fee affects subjects' preference for tariff structures, which is consistent with Hypothesis 4.

4.2.2. Flat-Rate vs. Two-Part Tariffs

The results reveal a stronger preference for flat-rate tariffs over two-part tariffs. When expected payments for both plans are the same at the base level, subjects choose the flat-rate tariff (FT^1) over the two-part tariff ($2PT^1$) (80.77%, $z = 10.87$, $p < 0.001$), which is significantly greater than 56.41% observed in the voice usage ($z = -6.42$, $p < 0.001$).

When the expected payment for a flat-rate tariff plan increases by 20% from the base level (FT^2), subjects are now practically indifferent between the the flat-rate tariff (FT^2) and the two-part tariff at the base level ($2PT^1$) ($z = 0.680$, $p = 0.497$). This is statistically different from the preference observed in the voice usage case ($z = -7.70$, $p < 0.001$).

When the expected payment for a two-part tariff plan decreases by 20% from the base level ($2PT^2$), subjects still prefer the flat-rate tariff (FT^1) over the new two-part tariff ($2PT^2$) (72.76%, $z = 8.041$, $p < 0.001$), which is greater than the proportion (41.35%) observed in the voice usage case. Note that it is only about 8% lower than the proportion observed at the base level, similar to the observation in the voice usage case. This result implies that the amount of fixed fee indeed affects subjects' preference for tariff structures in the same way as in the voice usage case, contrary to Hypothesis 4.

4.2.3. Three-Part vs. Two-Part Tariffs

As in the case of voice usage, subjects show a strong preference for three-part tariff plans over two-part tariff plans. We find that 75.00% prefer the three-part tariff plan ($3PT^1$) over the two-part tariff plan ($2PT^1$) at the base level($z = 8.947$, $p < 0.001$), which is significantly greater than the proportion observed in the voice usage case (58.65%) ($z = -8.24$, $p < 0.001$).

When the expected payment for a three-part tariff plan increases by 10% from the base level ($3PT^2$), 50.96% of the subjects choose the three-part tariff ($3PT^2$) over the two-part tariff at the base level ($2PT^1$), indicating indifference, which is inconsistent with the preference for $2PT^1$ over $3PT^2$ observed in the voice usage case.

When the expected payments for a three-part tariff plan and a two-part tariff plan decrease by 10% and 20% from the base level, respectively, 67.95% of the subjects prefer the three-part tariff ($3PT^3$) over the two-part tariff ($2PT^2$) ($z = 6.342$, $p < 0.001$), which is greater than the 58.65% observed in the voice usage case ($z = -4.33$, $p < 0.001$. The amount of fixed fee again affects subjects' preference for tariff structures, as in the voice usage case, contrary to Hypothesis 4.

Table 3. Discrete choice results of a preferred plan (voice).

Q1	FT[1]	FT[1]	FT[2]	FT[2]	3PT[1]	3PT[1]	3PT[2]	3PT[2]	3PT[3]	3PT[1]	3PT[1]	3PT[2]	3PT[3]	3PT[3]
Q2	2PT[1]	2PT[2]	2PT[1]	2PT[2]	2PT[1]	2PT[2]	2PT[1]	2PT[2]	2PT[2]	FT[1]	FT[2]	FT[2]	FT[1]	FT[2]
1s	176	129	67	52	183	149	114	84	183	156	262	227	221	266
2s	136	183	245	260	129	163	198	228	129	156	50	85	91	46
1 (%)	56.41	41.35	21.47	16.67	58.65	47.76	36.54	26.92	58.65	50.00	83.97	72.76	70.83	85.26
2 (%)	43.59	58.65	78.53	83.33	41.35	52.24	63.46	73.08	41.35	50.00	16.03	27.24	29.17	14.74
z-value	2.265	−3.058	−10.079	−11.778	3.058	−0.793	−4.757	−8.154	3.058	0.000	12.005	8.041	7.361	12.458
p-value	0.023	0.002	0	0	0.002	0.428	0	0	0.002	1	0	0	0	0

Table 4. Discrete choice results of a preferred plan (data).

Q1	FT[1]	FT[1]	FT[2]	FT[2]	3PT[1]	3PT[1]	3PT[2]	3PT[2]	3PT[3]	3PT[1]	3PT[1]	3PT[2]	3PT[3]	3PT[3]
Q2	2PT[1]	2PT[2]	2PT[1]	2PT[2]	2PT[1]	2PT[2]	2PT[1]	2PT[2]	2PT[2]	FT[1]	FT[2]	FT[2]	FT[1]	FT[2]
1s	252	227	162	140	235	198	159	136	212	136	216	181	176	226
2s	60	85	150	172	78	114	153	176	100	176	96	131	136	86
1 (%)	80.77	72.76	51.92	44.87	75.00	63.46	50.96	43.59	67.95	43.59	69.23	58.01	56.41	72.44
2 (%)	19.23	27.24	48.08	55.13	25.00	36.54	49.04	56.41	32.05	56.41	30.77	41.99	43.59	27.56
z-value	10.87	8.041	0.680	−1.812	8.947	4.757	0.340	−2.265	6.342	−2.265	6.795	2.831	2.265	7.928
p-value	0.000	0.000	0.497	0.070	0.000	0.000	0.734	0.024	0.000	0.024	0.000	0.005	0.024	0.000

Table 5. Preference for the second options (2s), controlled by data usage (dummy, logistic regression).

Q1	FT[1]	FT[1]	FT[2]	FT[2]	3PT[1]	3PT[1]	3PT[2]	3PT[2]	3PT[3]	3PT[1]	3PT[1]	3PT[2]	3PT[3]	3PT[3]
Q2	2PT[1]	2PT[2]	2PT[1]	2PT[2]	2PT[1]	2PT[2]	2PT[1]	2PT[2]	2PT[2]	FT[1]	FT[2]	FT[2]	FT[1]	FT[2]
z-value	−6.42	−7.77	−7.70	−7.39	−8.24	−4.30	−3.93	−3.62	−4.33	1.60	4.29	3.85	3.73	3.87
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.109	0.000	0.000	0.000	0.000

4.3. Subjects' Awareness and Conjecture of Usage

One notable finding is the difference in the accuracy of subjects' estimation of their usage amount for voice and data. We calculate the difference between their estimates and the actual value. After dropping outliers, the average difference is −5.88 (min) with a standard deviation of 71.68 for voice usage, and −0.61 (GB) with a standard deviation of 2.02 for data usage. (The negative values indicate that subjects overestimate their actual usage in both voice and data.) Note that we should examine the standard deviation, not the mean, to find out the closeness of subjects' usage estimates to their actual usage. Since we cannot directly compare the standard deviation of voice usage and that of data usage, we employ the coefficient of variation (CV), a statistical measure of the dispersion of data points in a data series around the mean.

The CV is 0.41 for voice usage, but it is 0.88 for data usage, which is more than twice that of voice usage. This notable difference in subjects' accuracy of estimation between voice and data usage is consistent with Hypothesis 2, which claims that data usage is more challenging for consumers to control than voice usage. It supports Hypothesis 3, which argues that the sense of controllability affects consumers' preference for tariff structures in different degrees for the voice and data usage.

4.4. Discussion

The results from the experiment are consistent with Hypotheses 1, 2, and 3. Subjects prefer flat-rate tariffs over three-part tariffs, and three-part tariffs over two-part tariffs. Their voice usage estimates are likely to be more accurate than those of data usage, and the preference is stronger in data usage than in voice usage. We conjecture that the salience and controllability in voice usage, which mainly stem from the "calling party payment" scheme, contribute to reducing the disutility from the uncertain amount of usage and payment, thus justifying the weaker preference for flat-rate tariff plans observed in voice usage. Furthermore, it seems that controllability possibly reduces reference uncertainty more than usage uncertainty, which could explain why the preference for three-part tariffs over two-part tariffs is stronger in data usage.

One might argue that the reason subjects had a lower sense of controllability in data usage is that several 3G plans with the monthly fixed fee greater than KRW 54,000 provide unlimited data. Thus, users have no reason to be aware of their data usage. However, the data suggests that the estimates of data usage by subjects who subscribe to LTE plans, which do not provide unlimited data, are likely to be far from optimal, as compared to the actual usage. The average data usage of subjects who subscribe to the 4G LTE plan of KRW 62,000 (LTE62) or greater fixed monthly fee, the average data usage quantities are 1.659 GB (LTE62), 1.957 GB (LTE72), 1.908 GB (LTE85), and 2.017 GB (LTE100), respectively, which are below the initial allowances (ranging from 5 GB to 20 GB).

Another possible explanation is that subjects have not yet formed a reference in data usage, which is a relatively newer service for them at the time of our experiment. Thus, it is not necessarily because the fluctuation of data usage is greater than that of voice usage. Although the coefficients of variation (CV) are not calculated for individual users, the CV of the subjects' actual voice usage is 0.84, which is less than 1. Meanwhile, that of their actual data usage is 1.02, which is greater than 1. If this can be applied on an individual level, we predict a higher fluctuation in data usage than in voice usage. Moreover, based on the prediction of Herweg and Mierendorff [27], if the result is mainly due to inexperience in the subjects' use of data services, they should have shown a stronger preference for flat-rate tariff plans than they do in the experiment.

Unlike the other hypotheses, Hypothesis 4 is not consistent with the present experimental results. The preference for flat-rate tariffs over two-part tariffs and three-part tariffs over two-part tariffs is stronger as the level of expected payment gets lower, thus implying that the preference for tariff structures is affected by the amount of fixed fee. However, we observe almost no difference in the preference between three-part tariffs and two-part tariffs regardless of the difference in the level of the expected payment. Overall, the preference for three-part tariffs, which is more pronounced in the data usage, is hard to explain via rational choice or a conventional loss-aversion model alone.

5. Conclusions

Adopting the idea of reference uncertainty from the GL model [10,11], and conducting a laboratory experiment, this paper investigates the effects of consumers' preference for tariff structures on their mobile plan choices. The present research exploits the fact that the fixed fee and initial allowance in three-part tariff can be regarded as the status quo or the initial wealth for consumers, and, using a simplified GL model, we hypothesize that tariff structures influence these uncertainties: flat-rate tariffs remove both uncertainties, two-part tariffs remove none, and three-part tariffs remove the reference uncertainty only. It was also hypothesized that the salience and the perceived controllability in voice usage, combined with the "calling party payment" scheme, contribute to reducing the disutility from uncertain usage amount, thus justifying the preference for flat-rate plans in the voice usage case. Moreover, it appears that the sense of controllability affects reference uncertainty more than payment uncertainty, which could explain why the preference for three-part tariffs is stronger in data usage.

This paper empirically test mobile plan choice with the experiment. In the first half, we collect responses on usage patterns and conjecture the subject's usage distribution by combining the answers with the information about his/her mobile plan subscriptions. In the second half, we ask subjects to state their preference for 14 pairs of mobile plans with different tariff structures (for both voice and data) generated from the conjectured usage distributions. Finally, we collect subjects' actual usage information where possible.

The results show that subjects prefer flat-rate tariffs over three-part tariffs and three-part tariff over two-part tariffs, and their estimates of voice usages are likely to be more accurate than those of data usage. Moreover, the preference is stronger in data usage than in voice usage. Subjects' preference for flat-rate tariffs over three-part tariffs is relatively weaker, especially in voice usage, while the preference for three-part tariffs is more pronounced in data usage. The results are consistent with the predictions that consumers' perceived differences in the controllability of voice usage and data usage lead to the difference in the reference uncertainty. In addition, there is a notable difference in subjects' accuracy of estimation between voice and data usage. An interpretation is that data usage is more challenging for users to control than voice usage.

In conclusion, consumers experience disutility from the reference uncertainty and wish to remove it, and they are more willing to do sowhen the expected payment is low. Moreover, the reference uncertainty creates more disutility for consumers than the payment uncertainty. The results are challenging to explain via a rational choice or a conventional loss-aversion model. Hence, the reference uncertainty, as described in the modified GL model, exists and influences consumers' choice of mobile plans. Overall, this research suggests that the current pricing of mobile telecommunication service may be further adjusted to derive more sustainable and practical tariff structures that meet both consumers and corporate goals. Especially, it implies that consumers tend to respond differently to voice and mobile plan choice due to different levels of uncertainty they perceive in each cases. Armed with the better understanding of consumer psychology provided by this study, future research will need to further explore ways to implement these findings into sustainable mobile policy. (The results also provide supportive experimental evidence for previous theoretical studies such as Bar-Gill and Stone [26] and Herweg and Mierendorff [27].)

Note, however, that even though the results are consistent with our hypotheses, they cannot exclude every alternative explanation. For example, it is difficult to rule out the possibility that the subjects' inexperience in using mobile data service (mostly less than three years as of 2012), relative to mobile voice services, influenced the results. (It depends on whether consumers actually become aware of their usage with time (e.g., [35]), or stay inattentive to past usage (e.g., [36]).) Thus, further investigation is necessary to solidify our conclusions. For example, analyzing individual choices using a random utility model could help attain a more robust conclusion regarding the effects of tariff structure preference. Note also that although our approach of conjecturing a subject's usage pattern by not using the same usage tables for every subject is useful for bringing their choices closer to that of real-world mobile plans, it is not useful in capturing the degree of disutility or uncertainty. These limitations need to be addressed in future studies.

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Abbreviations

The following abbreviations are used in this manuscript:

3G	Third Generation (mobile network)
CV	Coefficient of Variation
GB	Gigabyte
GL	Gain–loss
KRW	Korean Won (currency)
LTE	Long-Term Evolution (mobile network)
USD	United States Dollar (currency)

Appendix A. Major Mobile Subscription Plans (at the Time of Data Collection)

Table A1. Major smartphone plans in South Korea (3G).

	Initial Endowment Amount					
Flat Rate (KRW/mo.)	**SK Telecom**		**KT**		**LGU+**	
	Data	**Voice**	**Data**	**Voice**	**Data**	**Voice**
34,000	100 MB	150 min.	100 MB	150 min.	1 GB	150 min.
44,000	500 MB	200 min.	500 MB	200 min.	1 GB	200 min.
54,000	unlimited	300 min.	unlimited	300 min.	unlimited	300 min.
64,000	unlimited	400 min.	unlimited	400 min.	unlimited	400 min.
74,000	unlimited	600 min.	unlimited	600 min.	unlimited	600 min.
94,000	unlimited	1000 min.	unlimited	800 min.	unlimited	1020 min.

Table A2. Major smartphone plans in South Korea (LTE).

	Initial Endowment Amount					
Flat Rate (KRW/mo.)	**SK Telecom**		**KT**		**LGU+**	
	Data	**Voice**	**Data**	**Voice**	**Data**	**Voice**
34,000	550 MB	120 min.	750 MB	160 min.	750 MB	160 min.
42,000	1.1 GB	180 min.	1.5 GB	200 min.	1.5 GB	200 min.
52,000	2.0 GB	250 min.	2.5 GB	250 min.	2.5 GB	250 min.
62,000	5.0 GB	350 min.	6.0 GB	350 min.	6.0 GB	350 min.
72,000	9.0 GB	450 min.	10.0 GB	450 min.	10.0 GB	500 min.
85,000	13.0 GB	650 min.	14.0 GB	650 min.	14.0 GB	750 min.
100,000	18.0 GB	1050 min.	20.0 GB	1050 min.	20.0 GB	1200 min.

Appendix B. Captured Screen of the Experiments

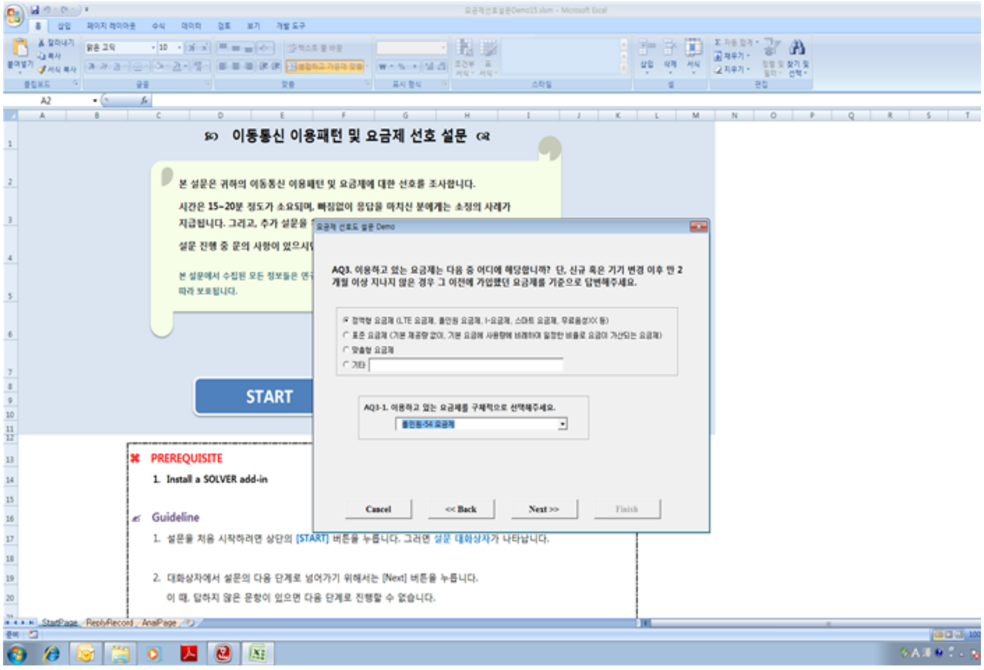

Figure A1. A subject enters her/his current mobile plan (in Korean). Specifically, the capture asks a subject's current mobile subscription plan. The subject chooses "All-in-One 54," a three-part tariff 3G plan provided by KT that charges KRW 54,000 as a fixed-fee, a little less than USD 50, and gives 150 min of the initial voice allowance and unlimited data. Table 1 provides more details.

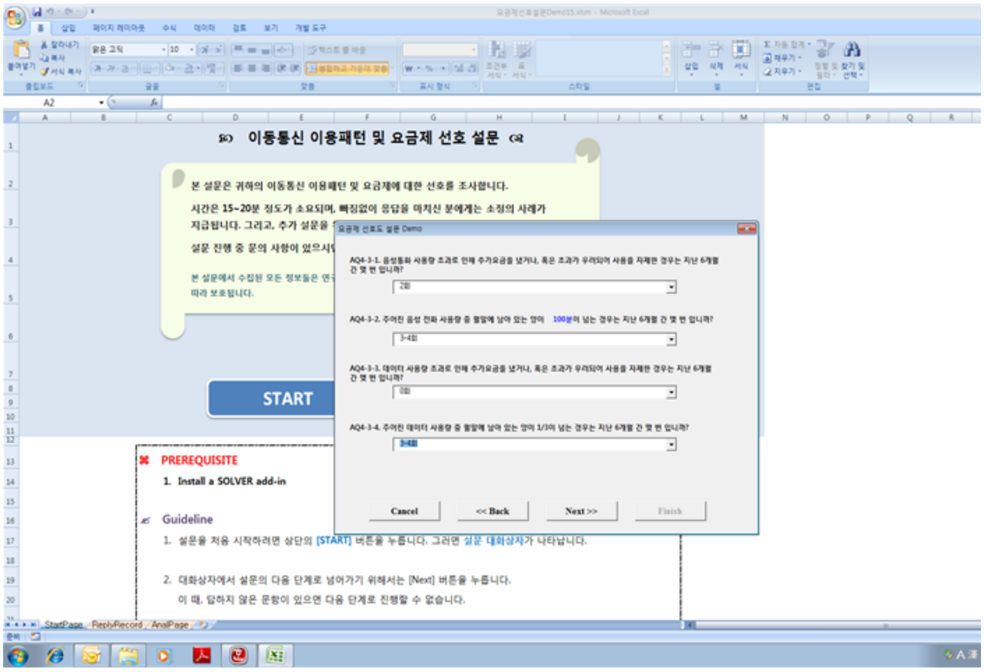

Figure A2. A subject enters her/his experience of over/underusage for the last six months (in Korean). Specifically, the capture asks a subject's experience of underusage and/or overusage for the last six months if the subject's subscription plan has the three-part tariff structure. Voice under/overusage is measured by minutes while data under/overusage is by the ratio of under/overusage amount to the initial data endowment.

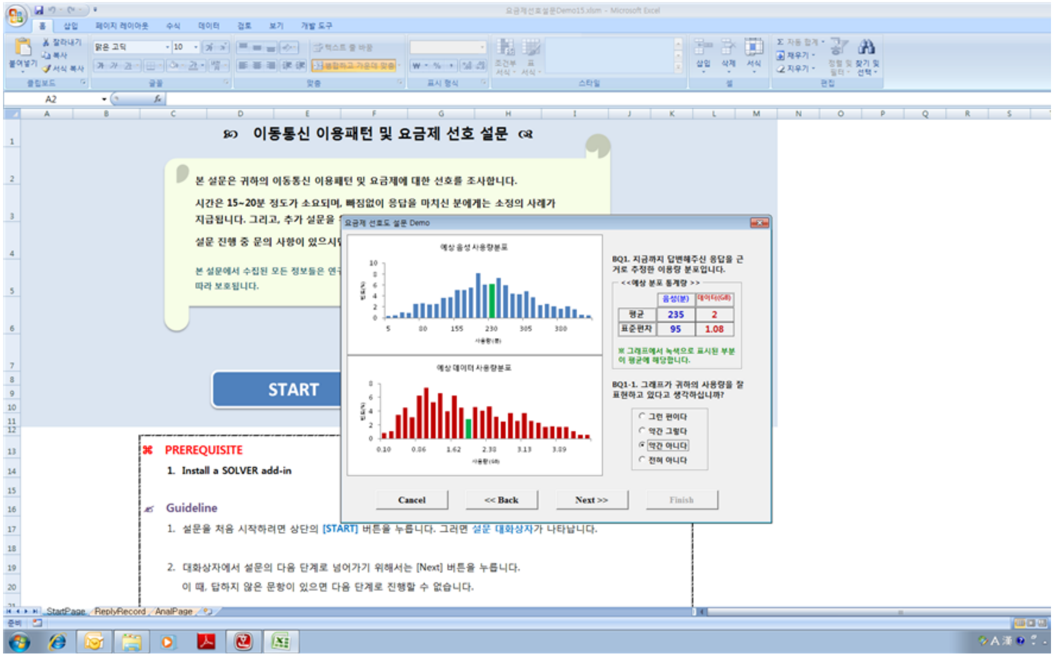

Figure A3. Conjectured usage distribution for a subject (in Korean). Specifically, the capture of the screen shows the individualized usage distributions generated for a subject, both voice, and data, based on their answers and our assessment. The bar graphs in Figure A3 visualize the conjectured usage distributions, blue one for voice and red one for data, respectively. The conjectured average voice usage is 235 min with a standard deviation of 95 min, and the conjectured data usage is 2GB with a standard deviation of 1.08G..

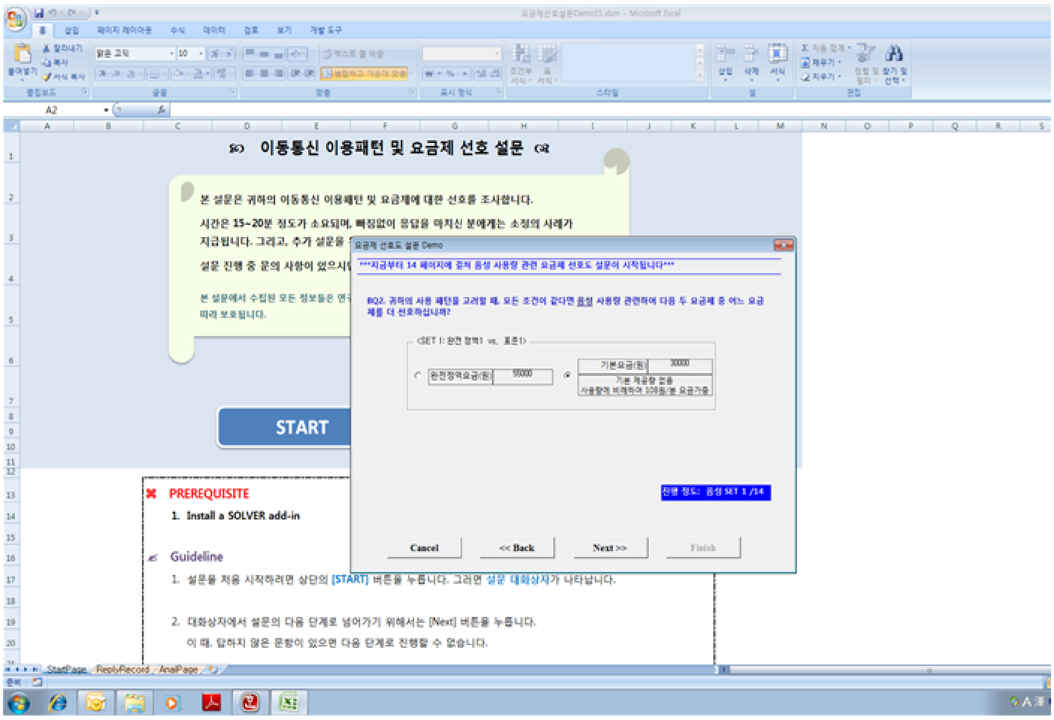

Figure A4. Mobile plan choice: flat-rate tariff vs. three-part tariff at the base level (voice, in Korean). Specifically, the capture of the screen shows a mobile plan choice between the flat-rate tariff plan of KRW 55,000 (about USD 50) and the two-part tariff plan with the fixed fee of KRW 30,000 and KRW 108 per minutes. The expected payments are designed to be the same, given the conjectured usage distribution shown in Figure A3.

References

1. Kridel, D.J.; Lehman, D.E.; Weisman, D.L. Option value, telecommunications demand, and policy. *Inf. Econ. Policy* **1993**, *5*, 125–144. [CrossRef]
2. Miravete, E.J. Choosing the Wrong Calling Plan? Ignorance and Learning. *Am. Econ. Rev.* **2003**, *93*, 297–310. [CrossRef]
3. Train, K.E.; Ben-Akiva, M.; Atherton, T. Consumption Patterns and Self-selecting Tariffs. *Rev. Econ. Stat.* **1989**, *71*, 62–73. [CrossRef]
4. Kling, J.P.; Van Der Ploeg, S.S. Estimating local call elasticities with a model of stochastic class of service and usage choice. In *Telecommunications Demand Modelling*; North–Holland: Amsterdam, The Netherlands, 1990.
5. Mitchell, B.M.; Vogelsang, I. *Telecommunications Pricing: Theory and Practice*; Cambridge University Press: Cambridge, UK, 1991.
6. Ascarza, E.; Lambrecht, A.; Vilcassim, N. When talk is "free": The effect of tariff structure on usage under two-and three-part tariffs. *J. Mark. Res.* **2012**, *49*, 882–899. [CrossRef]
7. Leider, S.; Şahin, Ö. Contracts, biases, and consumption of access services. *Manag. Sci.* **2014**, *60*, 2198–2222. [CrossRef]
8. Bar-Gill, O.; Stone, R. Pricing Misperceptions: Explaining Pricing Structure in the Cell Phone Service Market. *J. Empir. Leg. Stud.* **2012**, *9*, 430–456. [CrossRef]
9. Gerpott, T.J.; Meinert, P. Choosing a wrong mobile communication price plan: An empirical analysis of predictors of the degree of tariff misfit among flat rate subscribers in Germany. *Telemat. Inform.* **2017**, *34*, 303–313. [CrossRef]
10. Kőszegi, B.; Rabin, M. A Model of Reference-Dependent Preferences. *Q. J. Econ.* **2006**, *121*, 1133–1165.
11. Kőszegi, B.; Rabin, M. Reference-dependent risk attitudes. *Am. Econ. Rev.* **2007**, *97*, 1047–1073. [CrossRef]
12. Pagel, M. Prospective gain–loss utility: Ordered versus separated comparison. *J. Econ. Behav. Organ.* **2019**, *168*, 62–75. [CrossRef]
13. Kahneman, D.; Tversky, A. Prospect theory: An analysis of decision under risk. *Econom. J. Econom. Soc.* **1979**, *47*, 263–291. [CrossRef]
14. Sprenger, C. An endowment effect for risk: Experimental tests of stochastic reference points. *J. Political Econ.* **2015**, *123*, 1456–1499. [CrossRef]
15. Bell, D.E. Disappointment in decision making under uncertainty. *Oper. Res.* **1985**, *33*, 1–27. [CrossRef]
16. Loomes, G.; Sugden, R. Disappointment and dynamic consistency in choice under uncertainty. *Rev. Econ. Stud.* **1986**, *53*, 271–282. [CrossRef]
17. Gul, F. A theory of disappointment aversion. *Econom. J. Econom. Soc.* **1991**, *59*, 667–686. [CrossRef]
18. Delquié, P.; Cillo, A. Expectations, disappointment, and rank-dependent probability weighting. *Theory Decis.* **2006**, *60*, 193–206. [CrossRef]
19. Gill, D.; Prowse, V. A structural analysis of disappointment aversion in a real effort competition. *Am. Econ. Rev.* **2012**, *102*, 469–503. [CrossRef]
20. Knetsch, J.L.; Wong, W.K. The endowment effect and the reference state: Evidence and manipulations. *J. Econ. Behav. Organ.* **2009**, *71*, 407–413. [CrossRef]
21. Kőszegi, B.; Rabin, M. Reference-dependent consumption plans. *Am. Econ. Rev.* **2009**, *99*, 909–936. [CrossRef]
22. Song, C. An Experiment on Reference Points and Expectations. 2016. Available online: http://dx.doi.org/10.2139/ssrn.2580852 (accessed on 30 November 2020).
23. Lerner, J.S.; Keltner, D. Fear, anger, and risk. *J. Personal. Soc. Psychol.* **2001**, *81*, 146. [CrossRef]
24. McDaniels, T.L.; Axelrod, L.J.; Cavanagh, N.S.; Slovic, P. Perception of ecological risk to water environments. *Risk Anal.* **1997**, *17*, 341–352. [CrossRef] [PubMed]
25. Slovic, P. Perception of risk. *Science* **1987**, *236*, 280–285. [CrossRef] [PubMed]
26. Bar-Gill, O.; Stone, R. Mobile Misperceptions. *Harv. J. Law Technol.* **2009**, *23*, 49–118.
27. Herweg, F.; Mierendorff, K. Uncertain Demand, Consumer Loss Aversion, and Flat-Rate Tariffs. *J. Eur. Econ. Assoc.* **2013**, *11*, 399–432. [CrossRef]
28. Kahneman, D.; Knetsch, J.L.; Thaler, R.H. Experimental tests of the endowment effect and the Coase theorem. *J. Political Econ.* **1990**, *98*, 1325–1348. [CrossRef]
29. Tversky, A.; Kahneman, D. Loss aversion in riskless choice: A reference-dependent model. *Q. J. Econ.* **1991**, *106*, 1039–1061. [CrossRef]
30. Dowling, K.; Stich, L.; Spann, M. An Experimental Analysis of Overconfidence in Tariff Choice. 2020. Available online: http://dx.doi.org/10.2139/ssrn.3384033 (accessed on 30 November 2020).
31. Dowling, K.; Manchanda, P.; Spann, M. The existence and persistence of the pay-per-use bias in car sharing services. *Int. J. Res. Mark.* **2020**. [CrossRef]
32. Kim, H. "Because It's Too Cheap?" Korean Government Pause the Launch of SKT's Cheaper 5G Plans. Edaily. 2020. Available online: https://www.edaily.co.kr/news/read?newsId=02525606625997208&mediaCodeNo=257 (accessed on 30 November 2020). (In Korean)
33. Loewenstein, G.F.; Weber, E.U.; Hsee, C.K.; Welch, N. Risk as feelings. *Psychol. Bull.* **2001**, *127*, 267. [CrossRef]
34. Slovic, P.; Finucane, M.L.; Peters, E.; MacGregor, D.G. Risk as analysis and risk as feelings: Some thoughts about affect, reason, risk and rationality. In *The Feeling of Risk*; Routledge: Abingdon-on-Thames, UK, 2013; pp. 49–64.
35. Nevo, A.; Turner, J.L.; Williams, J.W. Usage-Based Pricing and Demand for Residential Broadband. *Econometrica* **2016**, *84*, 411–443. [CrossRef]
36. Grubb, M.D.; Osborne, M. Cellular Service Demand: Biased Beliefs, Learning, and Bill Shock. *Am. Econ. Rev.* **2015**, *105*, 234–271. [CrossRef]