An Empirical Model of the Effect of "Bill Shock" Regulation in Mobile Telecommunication Markets

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Abstract

In this paper, we develop an empirical model of consumer usage and price uncertainty under a three-part tariff plan. Using this model, we study the effects of the recently proposed "Bill Shock" regulation in the mobile phone industry, a proposal that would inform consumers when they use up the monthly allowance of their mobile phone price plan. Using a rich billing dataset, we estimate an industry model of calling, subscription and pricing. Our counterfactual simulations predict that the proposed regulation will have two conflicting effects on mobile phone companies' pricing decision: It will lead to an increase in fixed fees and a decrease in overage fees. Finally, we find that the price changes have different implications for different segments of consumers: Both consumer surplus and industry revenue will decrease for light users and increase for heavy users.

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1 Introduction

As of April 2013, an agreement between the FCC and mobile network operators will commit operators to alert consumers when they approach and exceed the voice, text, and data allowances included in their mobile phone plans. This agreement was reached as response to a proposed "Bill Shock" regulation, which requires mobile network operators to inform consumers when they use up the monthly allowance of their mobile phone price plan (U.S. mobile network operators charge consumers a three-part tariff: a fixed monthly fee, a monthly allowance of free calling minutes, and an overage fee per minute.). The point of the proposed "Bill Shock" regulation is to reduce consumers' uncertainty regarding the marginal price they are paying for the next unit of consumption so that they will not be shocked by the bill they receive at the end of the billing cycle. Under the three-part tariff pricing structure, the source of consumer marginal price uncertainty comes from consumers' usage uncertainty: They cannot keep perfect track of their usage, and so they don't know for sure whether their actual usage is below or above the monthly allowance (the marginal price changes drastically at the point of monthly allowance). This paper develops an empirical model of consumer usage and price uncertainty under the three-part tariff plan. We use this model to predict how mobile phone companies would adjust their pricing decisions if Bill Shock regulation were implemented, and consumer usage and price uncertainty were eliminated.

We present an empirical industry model in which consumers have price uncertainty when they make their calling decision on their mobile phones. This price uncertainty occurs because consumers are unsure of their exact usage relative to the number of free minutes (allowance) included in the plan. We model consumer price uncertainty by including a perception error (actual usage/perceived usage) in consumers' consumption decisions. We assume that the perception error has a mean of 1 and follows a log-normal distribution (We use a field study to support this crucial assumption in the model). With the perception error, consumers cannot keep track of their exact usage; instead, they recall their previous usage in error. The presence of the perception error can be interpreted as limited consumer attention in keeping track of the exact usage.

The industry model has, in total, three stages: First, mobile network operators decide the pricing structure of mobile phone plans; second, consumers decide whether to use mobile phones and, if so, which plan to subscribe to; and third, consumers make consumption decisions conditional on their chosen plan. The model is estimated using a rich billing dataset. We jointly estimate the consumers' preference for usage and the subscription to mobile phone services. We then back out the mobile network operators' marginal cost using the demand estimates and the optimal pricing condition. Given these estimates, we simulate the price and quantity changes in the counterfactual scenario in which the proposed regulation is implemented.

A crucial step in this estimation is to identify consumer price uncertainty. Our identification strategy is based on the lack of bunching at the point where the marginal price changes discontinuously: Under the assumption that the distribution of consumer preference for calling is smooth, if consumers were aware of their exact usage, a mass point of consumers would use exactly their monthly allowance of free minutes; such bunching does not appear in the data, and this is informative about the degree of consumer price uncertainty.

In the counterfactual analysis, we study the case in which the perception error is eliminated by Bill Shock regulation. We first allow consumers to readjust their subscription and consumption decisions assuming no price adjustment. We then allow mobile network operators to readjust their prices in response to Bill Shock regulation; and, after finding the new price equilibrium, we measure how consumer surplus and firm profit would change after the price adjustment.

Assuming no price adjustment, we estimate that mobile network operators would lose $650 million per month, or 33 percent of the industry revenue-from Bill Shock regulation. The profit loss comes from two sources: (1) loss in overage payments due to the reduction in the number of calls above the monthly allowance; and (2) loss in fixed fees due to consumers switching from plans with big allowance to plans with small allowance.

Allowing for the price adjustment, we predict that the proposed regulation has two conflicting effects on mobile phone companies' pricing decision: All major mobile network operators increase their fixed fees, with increases ranging from 39 to 45 percent, and decrease their overage fees, with decreases ranging from 57 to 63 percent.

Finally, we find that the price changes associated with the Bill Shock regulation have different implications for different segments of consumers. Both consumer surplus and industry revenue will decrease for light users and increase for heavy users.

Complementary theoretical work by Grubb (2013) shows that the welfare effects of Bill Shock regulation are ambiguous. Complementary empirical work by Grubb & Osborne (2013) predicts that the regulation will lower average consumer welfare by about $2 per year.

The data used in Grubb & Osborne (2013) refers to a specific type of consumers: university students who were enrolled with a single mobile network operator. The lack of consumer heterogeneity in the data prevents Grubb & Osborne (2013) from finding significant distributional effect of Bill Shock regulation. In contrast, the data used in this paper is nationally representative and covers all carriers. As a result, I am able to find more substantial distributional effect of Bill Shock regulation on different types of consumers. In particular, I find that benefits enjoyed by heavy users from Bill Shock regulation lead to the positive average welfare effect on consumers even though the majority of consumers will be hurt by the regulation.

The panel nature of data in Grubb & Osborne (2013) allows them to address consumers' beliefs and learning: similar to Grubb (2009), consumers have biased belief; consumers' biased beliefs are the reason why consumers would not increase calling as a result of a reduction in overage prices in their counterfactual simulations. In contrast, consumers have rational expectation in my model (the cross-sectional nature of my data prevents me from estimating consumers' beliefs.): consumers would increase calling as a result of a reduction in overage prices in my counterfactual simulations, and the increase in calling minutes due to lower overage prices is the dominant welfare effect.

The remainder of the paper is organized as follow: Section 2 presents the intuition of the model using diagrams. Section 3 proposes an empirical industry model with consumer usage and price uncertainty. Section 4 describes the billing dataset used for the estimation of the model. Section 5 discusses identification and estimation results of parameters in the model. Section 6 discusses the effects of Bill Shock regulation via counterfactual simulations. Section 7 concludes.

2 Intuition of the Model

Before introducing the formal model, we first use Figures 1-a through 1-d to show the intuition of the model proposed in this paper. These figures show one consumer's behavior under one particular plan with a monthly allowance of 120 minutes and an overage fee of \$0.60/min (if this consumer uses fewer than 120 minutes this month, the marginal price for each calling minute is 0; if this consumer uses more than 120 minutes this month, the marginal price jumps to \$0.60/min.)

Before the implementation of "Bill Shock" regulation, this consumer has uncertainty about her actual usage and the actual marginal price for the next calling minute. Figure 1-a demonstrates the existence of perception error ω as the ratio between this consumer's perceived usage x and her actual usage $q = x\omega$; she never observes the actual realization of ω, so she is never sure about what her actual usage $q = x\omega$ is and can make her consumption decision based only on her perceived usage x instead. Figure 1-b shows the impact of the perception error on this consumer's calling decision and overage payment: At any perceived usage x, there is strictly positive possibility that this consumer's actual usage $q = x\omega$ is already longer than 120 minutes and that she has to unintentionally pay an overage fee of \$0.60/min; hence, this consumer's expected overage payment is strictly positive at any perceived usage x and is smoothed out at around 120 minutes.

The implementation of "Bill Shock" regulation eliminates this consumer's uncertainty about her actual usage and the actual marginal price for the next calling minute. Figure 1-c shows the impact of the elimination of the perception error without price changes–i.e., this consumer will stop calling at exactly 120 minutes and will not pay any overage fees. Figure 1-d shows that the firm should readjust price structures in response to the elimination of the perception error; the firm should cut the overage fee to encourage this consumer to call more than 120 minutes and increase the monthly fixed fee to capture the additional value created from this consumer's increased number of calling minutes.

3 An Empirical Industry Model with Usage and Price Uncertainty

In this section, we propose an empirical industry model in which consumers have price uncertainty when they make their usage decision on their mobile phones. This price uncertainty is caused by consumers' uncertainty regarding their exact usage relative to the number of free minutes (allowance) included in the plan.

3.1 Model Setup

We make the following assumptions in the model: Consumers cannot perfectly recall their exact mobile phone usage, and their perceived (estimated) usage is different from their actual usage; however, on average, consumers have a correct perception of their usage, and their perception error (actual usage/perceived usage) follows a log-normal distribution. We conduct a field study to support this assumption. Please refer to the Appendix for details of the field study.

The industry model consists of three stages. In **stage 1**, mobile network operators set the pricing structure of their plans; in **stage 2**, consumers make subscription decisions (choose a plan from all the plans available in the market); in **stage 3**, consumers decide their number of monthly calling minutes conditional on the plan chosen.

We begin with the last stage and work backwards.

3.2 Stage 3: Consumers' calling decision

We consider consumers indexed by $i = 1, 2, \ldots, N_m$ in $m = 1, 2, \ldots, M$ markets. Consumers first decide whether to subscribe to a mobile phone service. Conditional on subscribing to the mobile service, consumer i chooses a plan from the set of available plans, indexed by $j = 1, 2, \ldots, N_{J_m}$, offered by carriers $k = 1, 2, \ldots, K_m$, and the number of calling minutes x_i using the plan. To use plan j, consumers must pay a monthly fixed fee, F_j; A_j minutes are included in plan j; once consumers use more than A_j minutes in a given month, they must pay a per-minute overage fee of p_j.

Consumer i faces a time constraint T. She chooses to allocate her time either to talking on her mobile phone or to spending her time on outside activities (the marginal utility of which is normalized to 1) subject to the time constraint T.[1] Conditional on choosing plan j, consumer i chooses the number of calling minutes x_{ij} and the quantity of time spent on the outside activities x_{i0} to maximize her surplus.

We model consumer price uncertainty by including a perception error in consumers' consumption decisions. With this perception error, consumers cannot keep track of their exact usage and recall previous usage incorrectly. The presence of the perception error can be interpreted as limited consumer attention to keeping track of exact usage. Under this specification, consumers' perceived usage is x_{ij}, while their actual usage is $q_{ij} = x_{ij}\omega$. Here, ω is the perception error that measures the ratio of actual usage over perceived usage. Since ω is not observed, consumers maximize their expected utility conditional on the distribution of ω:

$$\max_{x_{ij}} v_{ij}(x_{ij}) = \int_{\omega} \overbrace{\theta_i ln(x_{ij}\omega)}^{\text{utility from calling}} + x_{i0} + \overbrace{\alpha_i p_j \max\{(x_{ij}\omega) - A_j, 0\}}^{\text{disutility from payment}} dF(\omega). \tag{1}$$

$$\text{subject to} \quad \int_{\omega} (x_{ij}\omega) dF(\omega) + \underbrace{x_{i0}}_{\text{outside activity}} \leq \underbrace{T}_{\text{time constraint}}$$

Let x^*_{ij} be the value of x_{ij} that solves equation 1 (see Appendix for more details). The realized usage is the product of the optimal perceived usage and the perception error: $x_{ij} = x^*_{ij}\omega$. The maximum monthly utility from calling using plan j for consumer i is, hence,

$$v_{ij}(x^*_{ij}; \theta_i, a_i, A_j, p_j) = \int_{\omega} \theta_i ln(x^*_{ij}\omega) + \alpha_i p_j \max\{(x^*_{ij}\omega) - A_j, 0\} + T - (x^*_{ij}\omega) dF(\omega) \tag{2}$$

Discussion of the model choice We choose to incorporate the perception error in consumers' consumption choice to reflect the fact consumers have uncertainty about their actual usage relative to the allowance included in the three-part tariff plan. This certainly, in turn, translates into consumers' uncertainty about the exact marginal price for the next calling minute in the context of the three-part tariff plan. Different from the marketing literatures on two-part tariffs (Danaher (2002); Essegaier et al. (2002); Kumar & Rao (2006)), this modeling choice is specific to a three-part tariff context (as in Lambrecht & Skiera (2006); Iyengar et al. (2007); Lambrecht et al. (2007)).

The model proposed here differs from those in the previous literature on three-part tariff in a sense that it incorporates a new dimension of consumer usage uncertainty and price uncertainty that are consistent with the "Bill Shock" regulation. The same modeling approach could be applied to the context with a block-

[1] The time constraint ensures that the number of calling minutes is bounded at a marginal price of zero. Alternatively, we could assume that the value to calling has a satiation point; this assumption, however, will violate the basic monotonicity and non-satiation properties of consumer preferences, as described in Classical Demand Theory. Ultimately, we choose the time-constraint assumption to make sure that consumers' calling preferences are consistent with basic properties described in Classical Demand Theory.

pricing structure, in which the marginal price changes according to the cumulated usage, as with electricity pricing, but this approach would not be appropriate for a two-part tariff context, in which the marginal price does not change according to the usage.

3.3 Stage 2: Consumers' subscription decision

Utility from calling is only part of the consumer's utility from subscribing to a plan. In particular, the consumer suffers from the disutility of paying the plan's monthly fixed fee. We assume that the total monthly utility that consumer i enjoys from subscribing to plan j in market m is:

$$u_{ijm} = v(x^*_{ijm}; \theta_i, a_i, A_j, p_j) + Z'_{jm}\lambda + \alpha_i F_{jm} + \xi_{jm} + \sigma_\epsilon \epsilon_{ijm}, \tag{3}$$

where $v(x^*_{ijm})$, defined as in equation 2, is the maximum monthly utility from using plan j for consumer i; λ and α_i are taste parameters for plan j's attributes independent of monthly allowance and price, respectively. We include dummy variables for plan j's characteristics independent of monthly allowance, such as year, firm, and whether roaming and long distance minutes are included in the monthly allowance.

3.4 Stage 1: Mobile network operators' pricing decision

A mobile network operator's gross profit (i.e., profit before fixed costs) is

$$\begin{aligned}\pi_{fm}(\overrightarrow{F_m}, \overrightarrow{A_m}, \overrightarrow{p_m}, \overrightarrow{J_{fm}}) = N_m \sum_{j \in \overrightarrow{J_{fm}}} s_{jm}(\overrightarrow{F_m}, \overrightarrow{A_m}, \overrightarrow{p_m}, \overrightarrow{J_{fm}})(F_j - C_{fm} \\ + \int_i \{ \int_\omega p_j \max\{x^*_i\omega - A_j, 0\} - c_{fm}(x^*_i\omega)\, dF(\omega)\} dP_{ijm}(s_{ijm}, s_{jm})),\end{aligned} \tag{4}$$

where m denotes market, f firm, and j plan. $\overrightarrow{J_{fm}} = \{j = 1, 2, \ldots, J\}$ is a list of offered plans in market m with a corresponding list of monthly fixed fees $\overrightarrow{F_m} = \{F_{jm}\}_j$, allowances $\overrightarrow{A_m} = \{A_{jm}\}_j$, and overage fees $\overrightarrow{p_m} = \{p_{jm}\}_j$; N_m is total number of households in market m; s_{jm} is the market share of plan j in market m; C_{fm} is firm f's cost of serving one consumer for in market m; c_{fm} is firm f's marginal cost per minute in market m; $x^*_i\omega$ is the number of minutes used by consumer i choosing plan j; and dP_{ijm} is the distribution of consumers conditional on choosing plan j in market m.

Mobile network operators compete by choosing plans' pricing structures to maximize profits. A complete pricing-strategy profile for one mobile network operator in one market includes the number of plans and ,for each plan, the fixed fee, allowance, and overage fee. In the counterfactual analysis, we allow the mobile network operators to re-optimize their pricing strategy in response to regulation. To make the problem tractable, I restrict each mobile network operator's pricing strategy in each market to two variables: the level of fixed fees, LF, and the level of overage fees, Lp, keeping all of the other components in the pricing structure unchanged (that is, the number of plans and the allowances included in each plan unchanged). The initial level of prices corresponds to $LF = 1$ and $LP = 1$. If the mobile network operator f decides to increase the level of fixed fees LF in market m by 20 percent, this means that the fixed fees of all plans offered by this mobile network operator f in market m would be increased by 20 percent, and LF would increase from 1 to 1.2. Similarly, if mobile network operator f decides to decrease the level of overage fees Lp in market m by 20 percent, then the overage fees of all plans offered by this mobile network operator f in market m would be decreased by 20 percent, and Lp would decrease from 1 to 0.8.

The cost structure Mobile network operators incur two sources of costs–the per-consumer cost and the per-minute cost. The per-consumer cost includes the cost of customer service, billing, etc. If the demand for a given network's minutes exceeds the network's capacity, then some calls need to be dropped. We model the network's per-minute cost as including the shadow cost implicit in optimization with capacity constraints and demand uncertainty.

4 The Billing Dataset

The main data source for this paper is the bill-harvesting data collected by TNS Telecoms.

4.1 TNS national survey

TNS conducts a quarterly national survey of U.S. households. The sample used in the paper includes the years 2000-2001, or eight quarters in total. The historical nature of these data has several advantages: (1) In 2000-2001, voice was the major function of mobile phones, which provides a cleaner setting in which to focus on the voice usage of mobile phones only; (2) Mobile phones were more homogeneous in 2000-2001 than they are today due to the absence of smart phones; (3) Mobile phones were a new product in 2000-2001; this fact provides a cleaner setting for not considering the impact of family plans. Naturally, the older a dataset is, the more difficult it is to apply it to current issues. That said, a study based on such historical data can still provide useful implications for the present day: Even though text messages and data usage have become important functions of mobile phones, three-part tariffs apply to text messages and data usage, as well.

In its survey, TNS asks about households' characteristics and ownership of mobile phones. Among 263,707 observations appearing in the survey in 2000-2001, 262,826 have complete key demographic information. Among these 262,826 households, 130,259 (50%) of them own at least one mobile phone. 16,914 of these

130,259 households provide their mobile phone bill.

4.2 TNS mobile phone bills

As mentioned in the previous section, around 16 percent of households in the TNS national survey handed in their mobile phone bills. There are, in total, 17,155 mobile phone bills; we call these the bill data. In a separate file, 11,051 bills have detailed information on each outgoing and incoming call during the month; we call this the call detail data. Bill data can be uniquely matched with call detail data using quarter-household ID-bill number. The bill data and call detail data show the name of household's mobile operator. Table 1 shows the count of bills in bill data and call detail data by major mobile network operators in 2000-2001.

As a test of sample representativeness, the last column of Table 1 reports the aggregate market shares reported in Kagan's *Wireless Telecom Atlas & Databook* 2001 Volume 2. We find that the bill data and call detail data are representative, with a few exception. The difference between the market share of Cingular in bill-level data and that reported by Kagan may be explained by the fact that Cingular was established only at the beginning of 2001, as a joint venture between SBC Communications and BellSouth; the bill-level data include only Cingular bills in the year 2001 (not in the year 2000), while Kagan reports the market share of SBC and BellShouth as that of Cingular in the year 2000.

Table 2 shows the summary statistics of key variables included in the bill data. The bill data have two shortcomings. First, billed minutes reported in the data do not distinguish minutes that are charged because of overage fees (minutes that are over the allowance) from roaming and long distance minutes that are charged in the form of linear pricing for local and regional plans. Second, 4,057 bills recorded zero usage, which is inconsistent with the call detail data. The call detail data overcome these shortcomings.

The 11,051 bills with call detail information report, in total, 748,391 calls. For each call, we can see the time of the call, whether it is roaming, what charges apply to this call, and what long distance charges apply to this call. We refer to 111,148 calls that were charged a strictly positive price outside of the allowance as billed calls. Table 2 also shows the composition, duration, and charges of billed calls. Non-roaming overage calls are calls that have been billed, but are neither roaming calls nor billed long distance calls.

Based on this information, we can overcome the shortcomings in the bill data discussed above: We can compute how many billed minutes are due to overage fees (additional minutes that are over the allowance); how many billed minutes are roaming minutes; and how many are long distance minutes. Finally, by adding together the duration of all calls placed, we get the total number of minutes used.

Table 2 shows the average and maximum monthly charges of bills with billed calls outside of the allowance. Among 11,051 bills with call detail information, 6,100 bills (around 55%) have billed calls. Among these

6,100 bills, 3,495 bills (around 57%) have billed calls due to non-roaming overage charges.

4.3 Tariff data

MyRatePlan.com collects pricing plans charged by different mobile operators.[2] We use tariffs offered in the same period as the sample period (year 2000-2001) of the bill data to construct the choice set of consumers in each market. A plan is uniquely defined by five key characteristics: monthly fixed fee; allowance; overage fee; long distance price, and roaming fee. The plan's coverage is directly associated with the long distance and roaming fees: local plans charge a strictly positive price for both long distance calls and roaming calls; regional plans offer free long distance calls and charge a strictly positive price for roaming calls; national plans offer free long distance and roaming calls.

4.4 Data Matching and Construction of Estimation Sample

This section presents the process of matching the bill data with the tariff data. We define a market as an economic area-year pair.[3] We match bills with the tariff data using the market-operator-fixed fee listed in both sources and use 2,992 matched bills to construct the market share of plans.[4] Bills that belong to the five major operators account for 80 percent of matched bills in the sample. The five major operators are: Sprint, AT&T, Voicestream Wireless(T-mobile), Verizon, and Cingular. We aggregate all plans offered by operators other than the five major operators in each market. Among plans offered by the five major operators, 95 percent of matched bills have fixed fees in the $19.99-$59.99 range. For each major operator in each market, we aggregate plans with fixed fees higher than $59.99 into one plan.

The matched 2,992 bills cover 108 markets: 46 economic areas in the year 2000 and 62 economic areas in the year 2001. 39 economic areas in the year 2000 have fewer than 30 matched bills, and 41 economic areas in the year 2001 have fewer than 30 matched bills. These 80 markets have too few matched bills to approximate the market shares of plans and, thus, are excluded from the estimation sample. Among the remaining 28 markets, we also exclude one market from 2000 and one market from 2001 where the majority of bills belong to non-major carriers and non-major plans.

[2] http://www.myrateplan.com/.

[3] The Economic Area service areas are based on the Economic Areas delineated by the Regional Economic Analysis Division, Bureau of Economic Analysis, U.S. Department of Commerce February 1995 (1-172), with the following additions: Guam and the Northern Mariana Islands (173), Puerto Rico and the U.S. Virgin Islands (174), and American Samoa (175). The Federal Communication Commission has also designated the Gulf of Mexico (176) as an additional Economic Area.

[4] We distinguish between plans with the same market-operator-fixed fee, but that differ in terms of whether they offer free roaming calls or long distance calls. We double check the accuracy of matching by looking at whether free roaming calls or long distance calls recorded in the bill are consistent with the corresponding characteristics of the plan. We also check whether the usage level recorded in the bill is consistent with the allowance level of the plan and drop the matches that are inconsistent. Please refer to the Appendix for additional details on the data-matching process.

4.5 Estimation Sample

Table 3 shows the summary characteristics of key variables of aggregate-level and micro-level data in the estimation sample. At the aggregate market level, Table 3 shows summary statistics on the number of providers, the market shares of the biggest and smallest provider and the average number of plans offered per provider in each market; at the aggregate plan level, there are, in total, 577 plans in the 26 markets considered. Table 3 also shows the summary statistics on the key characteristics of plans offered; at the micro level, there are in total 1,987 cell phone bills in all 26 markets considered, table 3 shows summary statistics on key demographic variables and cell phone usage variables associated with cell phone bills. 1,987 cell phone bills are used to construct market shares of plans, providers in each of the 26 markets.[5]

5 Identification and Estimation Results

In this section, the model developed in section 4 is estimated. Table 4 shows the estimates of all parameters in the model and their standard errors. In the estimation of standard errors, I take into account both sampling error and simulation error as in Berry et al. (2004).

5.1 The identification and estimation results of consumers' preference parameters

We first estimate the distribution of preferences for calling on mobile phones, θ_i, and the distribution of the perception error ω, using individual calling data; we then estimate jointly with price coefficients, a_i and α_i, and non-price preference parameters λ_j, using market share, price, and plan characteristics data. Recall that consumers make a choice of plan based on the preference parameter θ_i, which is observed fully by consumers but not fully by the econometrician. For this reason, when observing consumption patterns, we need to take into account the bias created by selection into plans. We correct for this selection bias by constructing moments of the model's prediction on monthly calling minutes conditional on plan choices and subscribing to mobile phones. The conditioning on plan choices requires knowing the parameters of the model of plan choices (stage two in the model, given in equation (3)). [6]

Consumer i's monthly calling minutes on plan j, x_{ijm}, are obtained by solving equation 7; hence, x_{ijm} depends on the calling preference, θ_i, the price coefficient,a_i, the distribution of perception error, $F(\omega)$, the

[5]One issue is that many plans have very few bills, and this may translate into measurement errors in the approximated market shares. Since there are no aggregate data available on the market shares of plans, it is hard to know the magnitude of measurement errors in the approximated market shares. In principle, the approximated market shares should be close to the true market shares of plans when cell phone bills are randomly sampled.

[6]We jointly estimate the parameters of the distribution of calling preferences, marginal utility of income, and perception errors, together with the plan choice parameters, as in Lee (Forthcoming).

monthly allowance of plan j, A_j, and the overage fee of the plan j, p_j. The calling data are the measurement of monthly calling minutes at the individual level. We estimate the distribution of θ_i, a_i and ω by matching moments of the model's prediction of monthly calling minutes to moments in the calling data.

Five sets of moment conditions are used in the estimation: (1) the probability that the monthly calling minutes fall in between 90 percent and 110 percent of the allowance; (2) the mean of monthly calling minutes for the eight combinations of three demographic groups (family, age, and rent); (3) the coefficient of variation in monthly calling minutes; (4) the correlation of the monthly calling minutes with the overage fee of the plan chosen by the two income levels; and (5) the covariance of demand-side instruments, Z^d_{jm}, with the unobserved demand shock ξ_{jm}. On the left-hand side are moments from the model prediction, with the corresponding moments in the data on the right-hand side. Please refer to the Appendix for the details on the estimation algorithm. Please refer to the Appendix for details on the estimation strategy.

5.1.1 Identification and estimation result of the perception error

The perception error is identified using the smoothness of the distribution of the usage ratio around 1 and the parametric assumption on the perception error. Figure 2 shows the histogram of the usage ratio in the data: there is no clear mass point in the distribution of the usage ratio around 1. The perception error is assumed to follow a log-normal distribution with parameters μ and σ_ω, which are the mean and standard deviation of ω's natural logarithm. In addition, we also assume that consumers have, on average, correct perception of their actual usage–i.e., $E(x_{ij}\omega) = x_{ij}E(\omega) = x_{ij}$. Given that ω is log normal, this implies that $\mu = \frac{-\sigma_\omega^2}{2}$. Under these parametric assumptions, the parameter σ_ω determines the distribution of the perception error ω.

σ_ω is identified by the key moment in the data: the probability of the usage ratio being between 0.90 and 1.10–that is, the probability that consumers' actual usage level is between 90 percent and 110 percent of the monthly allowance. Table 5 compares this moment in the data and the same moment simulated from the model by setting the key parameter σ_ω at different levels. σ_ω is estimated to be 0.58, which means that the variance of the perception error is around 0.40.[7] Table 5 also shows the value of the key moment for two other values of the variance of ω–specifically, 25 percent and 50 percent of the estimated value. Table 5 confirms the discussion in the identification section: When σ_ω is zero–i.e., consumers have a precise perception of their actual usage level–a large proportion of consumers end up using between 90 and 110 percent of their allowance because of the discontinuity in the marginal price. The larger the variance in consumers' perception error is–i.e., the larger σ_ω–the lower is the proportion of consumers who end up using between 90 and 110 percent of their allowance.

[7]Under log-normal distribution, the variance of ω equals to $e^{\sigma_\omega^2} - 1)e^{2\mu+\sigma_\omega^2} = e^{\sigma_\omega^2} - 1$.

5.1.2 Identification of estimation results of price coefficients

There are two price coefficients in the model: the price coefficient at the plan choice stage, α_i, which is the price coefficient corresponding to the monthly fixed fee; and the price coefficient at the consumption choice stage, a_i which is the price coefficient corresponding to the overage fee of the plan. These two price coefficients are identified separately using two different sets of moments. Although fixed fees are highly negatively correlated with overage fees, there are still significant variations in fixed fees of plans charging the same overage fees.

The price coefficient corresponding to the monthly fixed fee, α_i, is identified using moment (5), the covariance of demand-side instruments, Z^d_{jm}, with the unobserved demand shock, ξ_{jm}. Our instruments for the monthly fixed fee of plans follow standard practice in demand estimation on aggregate data. First, we allow observed product characteristics, Z_{jm}, to instrument for themselves. Observed product characteristics include dummy variables for non-minutes plan characteristics such as firm, year, etc. Second, we account for price endogeneity by instrumenting for it with the average price of plans with similar allowance levels offered in the same economic area groupings, but outside the same economic area.[8] We discretize the allowance level to six different groups: smaller than 100 minutes; 100 to 200 minutes; 200 to 300 minutes; 300 to 400 minutes; 400 to 600 minutes; and more than 600 minutes. Following Hausman (1997), these are often called Hausman instruments. These instruments have been used for demand estimation in settings such as Hausman (1997) and Nevo (2001).

The price coefficient corresponding to the overage fee, a_i, is identified using moment (4), the correlation of the monthly calling minutes with the overage fee of the plan chosen by the two income levels. The variation in overage fees comes from the fact that big plans are usually associated more with lower overage fees than small plans are; with the presence of perception error, consumers' perceived marginal price is flatter for big plans than for small plans for two reasons: (1) Consumers have a smaller probability of paying overage fees for big plans than for small plans at any given perceived usage level; and (2) if they pay overage fees, they pay a lower per-minute price for big plans than for small plans. Consumers with the same preference (same θ_i in equation (1)) end up choosing different plans sizes because of a different realization of their logit error (ϵ_{ij} in equation (3)), which is assumed to be uncorrelated with plans' overage fees. For consumers with different preferences, we construct moment (4) conditional on the plan choice; hence, the private information that consumers have at the plan choice stage is already accounted for.

The second and third rows of Table 6 present the mean and standard deviation of the price elasticities in terms of major mobile network operators's market shares with respect to the fixed fee levels. The subscription

[8]The Economic Area Groupings also know as Regional Economic Area Groupings for 220 MHz which were created by Commission staff are an aggregation of economic areas into 6 regions excluding the Gulf of Mexico.

price elasticity is estimated to be -0.61.

The fourth and fifth rows of Table 6 present the mean and standard deviation of the price elasticities in terms of overage minutes (the number of minutes that are charged with overage fees) of major mobile network operators with respect to the overage fee levels. The overage minutes' price elasticity of a particular firm in each market is computed as the percentage change of the firm's number of overage minutes when the overage fees of all plans offered by this firm in this market are increased by one percent, while holding prices of other firms constant. For example, Sprint was operating in 20 out of 26 markets in the estimation sample; if Sprint increases the overage fees of all plans in one market by one percent, while holding prices of other firms in the same market constant, Sprint's number of overage minutes would, on average (average across markets where this firm is present), decrease by 2.52 percent.

5.2 The identification and estimation results of costs

As mentioned in the discussion of cost structure in the previous section, there are two major sources of cost for one mobile network operator in one market: the cost per customer and the cost per minute, which are denoted by C_{fm} and c_{fm}, respectively, for firm f in market m. We use the profit-maximization problem of the mobile network operator f in market m to identify these two components of costs for each firm-market pair. This specification gives a linear approximation to firms' cost structure; it does not account for economies of scale.

In the counterfactual analysis, we allow the mobile network operators to re-optimize their pricing strategy in response to the regulation. To make the problem tractable, we restrict the pricing strategy of each mobile network operator in each market to two variables: the level of fixed fees LF and the level of overage fees Lp, keeping all the other components in the pricing structure unchanged (the number of plans and allowances included in each plan are kept unchanged). Hence, the first-order condition of profit with respect to the level of fixed fees and overage fees provides two optimization conditions to identify the cost per customer and the cost per minute.

Discussion of the cost-per-consumer estimates The estimated cost per consumer is much lower than Merrill Lynch's measure because its measure of monthly operating cost per consumer is computed using the average revenue per consumer reported by firms and the accounting margin; and firms usually include the fixed monthly operating costs as defined in equation 16 as part of the accounting cost, which is divided by the number of consumers in the computation of the accounting margin per consumer. The fixed monthly operating costs do not increase with the marginal increase in the number of consumers and, hence, should not be counted in the cost per consumer from an economics point of view.

Discussion of cost-per-minute estimates As discussed in the industry model section, the marginal cost of one minute is a linear approximation of the cost structure imposed by the capacity constraint. Before hitting the network's capacity constraint, the marginal cost of one minute is zero; once the capacity constraint is reached, there is a sudden jump in the marginal cost per minute. The effect of the capacity constraint is presented in the form of dropped calls in reality.

During the sample period, unlimited plans were uncommon, and most were associated with high overage fees. This pricing structure was partially due to the high capacity constraint that mobile network operators were facing at the beginning of the industry. The cost per minute is estimated through the profit-maximization problem of mobile network operators with respect to overage fees; thus, the cost-per-minute estimates reflect the level of the capacity constraint that made the overage fees observed in the data optimal. As mobile network operators acquired more spectrum and lessened the capacity constraint with respect to voice traffic, more unlimited plans have been offered in the last few years.

6 The Effects of "Bill Shock" Regulation

As discussed above, the lack of bunching of call minutes at the monthly allowance level is indicative of consumer uncertainty regarding price. We model consumers' perception error in recalling past usage as the source of such price uncertainty. In other words, consistent with this modeling strategy, we now simulate the effects of the "Bill Shock" regulation on mobile network operators' profit and pricing decisions by running a counterfactual in which we eliminate the consumers' perception error.

We first show what would happen to mobile network operators' profit when the pricing structure of calling plans remains unchanged. While this first counterfactual is not realistic in terms of predicting actual changes, it provides a useful indication of how consumer information on marginal price affects consumer demand and how firms' pricing incentives change as a result. In the second stage of the counterfactual, we allow mobile network operators to adjust their pricing structures and show what their new price strategies would be.

In the counterfactual analysis, perception error is eliminated for all consumers. Consumers' calling decisions will follow the standard calling model, but without perception error. Consumers' subscription decisions and mobile network operators' pricing decisions will also change according to the model of subscriptions and pricing.

6.1 The effects with the unchanged pricing structure

Table 8 presents the monthly per-household and total effect of the "Bill Shock" regulation, keeping the pricing structure unchanged. The table shows that the monthly industry profit would be decreased by $642 million if mobile network operators kept prices unchanged after the elimination of consumers' perception error. More than half of this loss would come from the $335 million decrease in monthly overage payments. After consumers receive information on their usage level and no longer have uncertainty regarding marginal price, 63 percent of subscribing consumers would use exactly their allowance, and the probability of overage decreases from 0.21 to 0.05. Consumers' plan switching drives this result. If consumers are uncertain about price, they may choose a large-allowance plan as a means to insure against unexpected overage payments (this is consistent with the fact that the majority of consumers use less than the allowance included in their plan before the regulation). If price uncertainty is eliminated, such consumers switch to a lower-allowance plan, which charges a lower fixed fee. Specifically, in Table 12, We distinguish between large and small plans: For a given consumer, a large plan is defined as one with an allowance that is greater than consumer demand at zero price. After regulation, consumers are more likely to choose a plan that is not too large, and, hence, there is a big increase in the number of people using exact allowance and not going over. Consumer plan switching also leads to a decrease in industry profit.

6.2 The effects with price response

To compute the new price equilibrium when the perception error is eliminated for all consumers under the "Bill Shock" regulation, we define the pricing strategy of each mobile network operator f in each market m as: readjusting the level of fixed fees LF_{fm} of all plans and the level of overage fees Lp_{fm} of all plans while keeping the number of plans and the allowance in each plan unchanged. The new price equilibrium is the Nash equilibrium of firms' pricing strategy in the absence of consumer perception error. Table 9 shows the changes in fixed fees and overage fees in the new price equilibrium: All major mobile network operators increase their fixed fees, with increases ranging from 39 to 45 percent, and decrease their overage fees, with decreases ranging from 57 to 63 percent.

Table 10 shows that the impact of the Bill Shock regulation on profits is close to zero. This contrasts with the profit loss predicted in the first counterfactual stage, reported in Table 8. There are two reasons for this difference. One is that the decrease in overage fees leads to more consumers incurring overage payments, from 5 to 42 percent. The second reason is that lower overage fees increase consumer valuations for the plan, which, in turn, allows network operators to increase fixed fees.

In terms of welfare, the elimination of consumers' perception error has two conflicting effects: On the extensive margin, the increase in fixed fees enlarges the gap between the fixed fees and the monthly cost per consumer; this price increase leads to a decrease in the penetration rate from 55 to 48 percent and to a loss in welfare. On the intensive margin, the decrease in overage fees shrinks the gap between the overage fees and the marginal cost per minute; this price reduction leads to an increases in calling from 115 to 134 minutes per household per month and to a gain in welfare. The welfare gain from the intensive margin surpasses the welfare loss from the extensive margin, resulting in a positive net welfare effect. The welfare gain is captured by consumers (two-percent increase in consumer surplus), while the industry profit does not change.

Finally, we find that price changes have different implications for different segments of consumers: Table 11 displays the changes in consumers surplus and industry revenue where consumers are classified according to their preference parameter (the lower quartiles corresponding to lighter users). Table 11 shows that both consumer surplus and industry revenue will decrease for light users, while both consumer surplus and industry revenue will increase for heavy users.

7 Conclusion

In this paper, we tackle the substantive question of what will happen to firm profit and consumer welfare when a consumer protection policy is enacted to provide consumers with more information. To make it more realistic, we allow firms to re-adjust their pricing practices in response to the policy to verify that any benefits to the consumer survive in equilibrium. We find that, in the new equilibrium, consumers will still benefit while industry profit will not change.

Academic researchers will benefit from the modelling approach used in this paper. Understanding the effect of consumer protection policies on firms' marketing strategies is not an easy task. The challenge lies in the fact that these policies are often proposed because consumers' behavior deviates from the standard economic model with fully informed and rational agents. A model that attempts to incorporate the source of consumers' limited information and bounded rationality has the danger of deviating so far from the standard economic model that it is not estimable and cannot be used to make any reasonable predictions on firms' marketing strategies in response to the regulation. We overcome that challenge by finding the right degree of deviation in the modeling approach: in our model, consumers make judgment mistakes, but they know that they make these mistakes and take this factor into account in their utility-maximization problem.

Industry practitioners and the society at large will also benefit from the findings in this paper. Firms are often against consumer protection policies because they claim that they will hurt firms' profit. In this paper, we find that cell phone companies will, indeed, lose money if they don't readjust their pricing strategies in response to Bill Shock regulation. Once they fully readjust their pricing strategies, however, industry profits will remain unchanged while consumers will benefit.

Future research could extend the model proposed in this paper to study the effect of consumer protection policies in other industries and settings. It would be interesting to see how firms' marketing strategies will change differently in other settings and what the implications of this difference for industry profit and consumer welfare would be.

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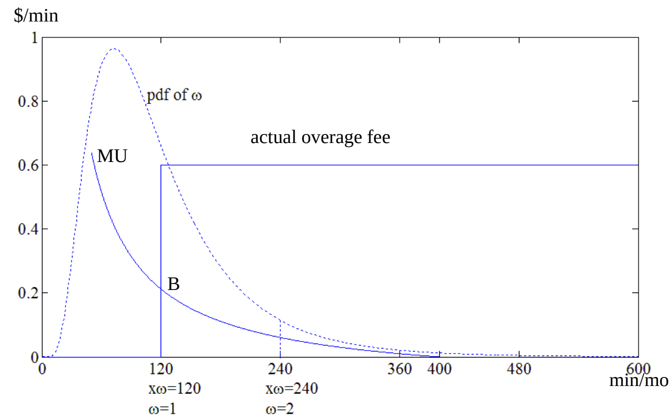
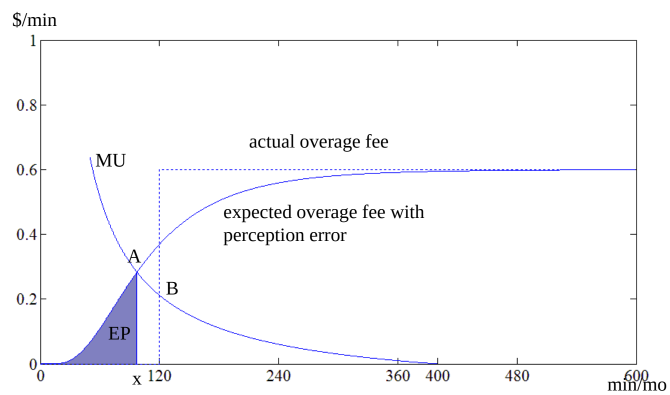
Figure 1-a: Demonstration of the perception error



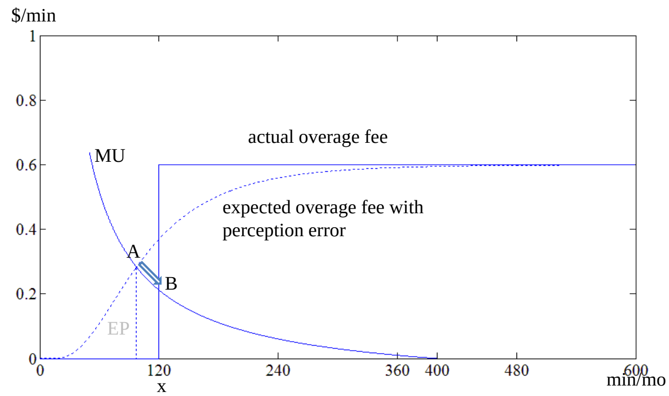
This graph demonstrates the existence of perception error of one particular consumer under one particular plan. This consumer's calling preference is represented by the curve MU (marginal utility of calling). If the marginal price of calling is zero for the whole month (unlimited plan), this consumer would like to stop calling at 400 minutes. However, the actual overage fee that this consumer faces is 0 when she calls fewer than 120 minutes and jumps to \$0.60/min when she calls more than 120 minutes. This consumer has uncertainty about her actual usage $q = x\omega$: At any perceived usage x, she never knows what the exact realization of her perception error $\omega = \frac{q}{x}$ is (it could be the case that $\omega = 1$, which means that she has the correct perception of her actual usage; it could also be the case that $\omega = 2$, which means that even though her perceived usage is $x = 120$, her actual usage is $x\omega = 240$.).

Figure 1-b: Demonstration of the impact of the perception error on consumer's calling decision and overage payment



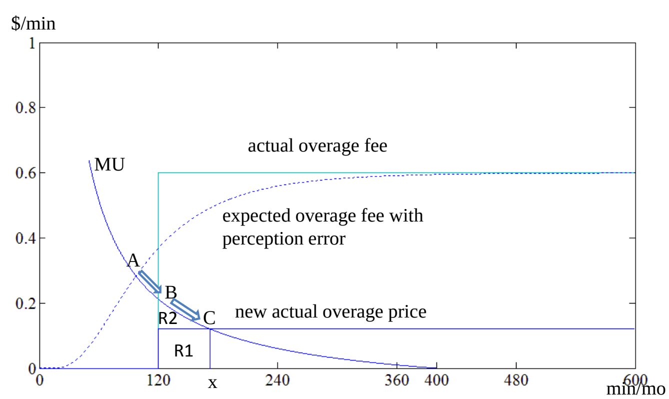
In this graph, the real marginal price per minute is 0 when the monthly calling minutes are fewer than 120 minutes and then jumps to \$0.60/min. If the consumer is perfectly certain about her usage, she will stop calling at exactly 120 minutes in this example. With the perception error, the perceived usage is different from the actual usage: At any perceived usage, there is a chance that the actual usage passes the 120 minutes threshold and the \$0.60/min overage fee applies; taking this fact into account, the perceived marginal price per minute is positive at any perceived usage. This consumer will stop calling at point x. The expected overage payment is represented by the area EP.

Figure 1-c: Elimination of perception error without price changes



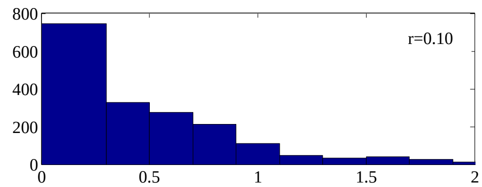
Once the perception error is eliminated, this consumer knows her actual usage and will stop calling with certainty at the intersection of her marginal utility curve and the actual overage fee, which is point B in this graph. The consequence is that this consumer will no longer pay any unintentional overage fees. If the firm does not adjust prices, it means a revenue loss (presented by area EP) for the firm.

Figure 1-d: Price changes after the elimination of perception error



To recover the revenue loss caused by the elimination of the perception error, the firm will cut the overage fee. This consumer will increase the number of calling minutes from point B to point C. The increase in this consumer's monthly calling minutes helps the firm to recover the revenue from two sources: the increase in overage fee payments (R1 in the graph) and the increase in monthly fees to capture additional value created by this consumer (R2 in this graph).

Figure 2: Histogram of the usage ratio in the data



This graph shows the histogram of the usage ratio in the data. Usage ratio is defined as the ratio of monthly calling minutes over total number of free minutes included in the plan. r is the radius of interval used for the histogram: the distance between the boundary of the interval and the center of the interval. In this histogram, r=0.10: the histogram of the usage ratio around 1 is approximated by the number of observations with usage ratio between 1-0.10 and 1+0.10.

Table 1: Count of bills and market share of major mobile network operators

Bill count in bill data			
mobile network operator	bill count	percentage	market shares (Kagan)
Sprint	1,327	8%	9%
AT&T	2,218	13%	12%
Voicestream Wireless(T-mobile)	476	3%	4%
Verizon	3,540	21%	25%
Cingular	1,636	10%	19%
Others	7,958	46%	31%
Total	17,155	100%	100%
Bill count in call detail data			
mobile network operator	bill count	percentage	market shares (Kagan)
Sprint	1,100	10%	9%
AT&T	1,618	15%	12%
Voicestream Wireless(T-mobile)	380	3%	4%
Verizon	2,430	22%	25%
Cingular	856	8%	19%
Others	4,667	42%	31%
Total	11,051	100%	100%

Table 2: Summary statistics of bill data and call detail data

Bill data					
variable	number of bills	mean	std. dev.	min	max
fixed fee $/mo	16,894	32.20	22.80	0.00	349.98
free min used/mo	16,986	115.84	269.91	0.00	5473
billed min/mo	16,986	36.67	148.03	0.00	3256
total min used/mo	16,986	154.29	329.03	0	5715
Call detail data: billed calls					
bills with billed calls	number of bills	percent	average payment	max payment	
roaming only	1,359	22%	6.58 $/mo	521.14 $/mo	
long distance only	2,681	44%	4.57 $/mo	165.69 $/mo	
roaming and long distance	1,057	17%	9.02 $/mo	287.14 $/mo	
non-roaming overage	3,495	57%	20.06 $/mo	438.90 $/mo	
bills with billed calls	6,100	100%	16.53 $/mo	620.45 $/mo	
billed calls	number of calls	percent	average duration	average payment	
roaming only	6,591	7%	2.58 min	1.36 $/call	
long distance only	13,217	11%	3.28 min	0.93 $/call	
roaming and long distance	4,098	4%	2.83 min	2.33 $/call	
non-roaming overage	87,242	77%	2.66 min	0.80 $/call	
total billed calls	111,148	100%	2.74 min	0.91 $/call	

Fixed fee is the monthly fixed fee of the three-part tariff plan. Free minutes used indicates total number of minutes used during the month for which there is no charge (either free minutes included in the allowance or free off-peak minutes). Billed minutes are minutes that are charged a strictly positive price (either minutes outside of the allowance, or roaming/long distance calls that are usually not free for local and regional plans). Total minutes used are the sum of free minutes used and billed minutes.

Table 3: Summary statistics in the estimation sample

Aggregate data: Market Level					
Variable	number of market	mean	std. dev.	min	max
number of providers per market	26	4.19	0.69	3	5
market share of the biggest provider	26	0.26	0.06	0.16	0.39
market share of the smallest provider	26	0.05	0.02	0.00	0.10
average number of plans per provider	26	5.22	1.58	2.40	8.75
Aggregate data: Plan Level					
Variable	number of plan	mean	std. dev.	min	max
fixed fee ($/mo)	577	40	17	15	128
allowance (min/mo)	577	311	238	0	1400
overage fee ($/min)	577	0.35	0.07	0.18	0.65
free long distance calls	577	0.48	0.50	0.00	1.00
free roaming calls	577	0.27	0.44	0.00	1.00
market share	577	3%	2%	0%	16%
Micro data					
Variable	number of hh	mean	std. dev.	min	max
monthly calling minutes (min/mo)	1,987	185	298	0	3169
family	1,987	0.77	0.42	0.00	1.00
head age over 55	1,987	0.35	0.48	0.00	1.00
renting	1,987	0.21	0.41	0.00	1.00
high income	1,987	0.85	0.36	0.00	1.00
prob of incur overage charges	1,987	17%	38%	0%	100%
overage charges ($/mo)	1,987	17	62	0	729

Table 4: Estimates of parameters in the model

	parameter estimate	standard error	interpretation
logit standard error	66.94	32.19	
mean preference parameter	4.93	0.60	
standard deviation of unobservable heteogeneity	0.87	0.21	
standard deviation of log of perception error	0.33	0.29	
price coefficient with respect to the overage price	-19.80	56.96	
income effect with respect to the	3.12	68.60	
preference shifter: family dummy	0.01	0.12	
preference shifter: hh head age over 55 dummy	-0.07	0.15	
prefence shifter: renting dummy	0.03	0.22	
year dummy: year 2000	-80.56	32.56	compared with year 2001
AT&T dummy	-100.62	16.10	compared with Verizon
Cingular dummy	-192.34	31.91	compared with Verizon
Sprint dummy	-169.34	30.29	compared with Verizon
VoiceStream (T-mobile) dummy	-318.97	30.16	compared with Verizon
Other carrier dummy	-245.11	43.78	compared with Verizon
free long distance dummy	-187.11	18.57	
free roaming dummy	16.44	16.29	
price coefficient with respect to the fixed fee	-22.60	0.54	
income effect with respect to the fixed fee	4.69	18.17	

Table 5: Comparison of the moments from model simulations and from data

	prob of usage ratio is between 0.90 to 1.10
data	0.06
model simulation: variance of omega=0.40 ($\sigma_\omega = 0.58$)	0.07
model simulation: variance of omega=0 ($\sigma_\omega = 0$)	0.70
model simulation: variance of omega=0.10 ($\sigma_\omega = 0.31$)	0.13
model simulation: variance of omega=0.20 ($\sigma_\omega = 0.43$)	0.10

This table compares the probability of the usage ratio being between 0.90 and 1.10 (the probability that consumers' actual usage level is between 90% and 110% of the number of free minutes included in the chosen plan) in the data and the same moment simulated from the model by setting the key parameter σ_ω at different levels. σ_ω is estimated to be 0.58, which means that the variance of the perception error is around 0.40 (under log-normal distribution, the variance of ω equals to $(e^{\sigma_\omega^2} - 1)e^{2\mu+\sigma_\omega^2} = e^{\sigma_\omega^2} - 1)$. Table 5 also shows what the key moment would be if the variance of perception error were zero, 25% (variance of ω=0.10, $\sigma_\omega = 0.31$) and 50% (variance of ω=0.20, $\sigma_\omega = 0.43$) of the estimated level.

Table 6: Estimates for price elasticities

	Sprint	AT&T	Voicestream	Verizon	Cingular
number of markets	20	26	13	20	12
mean own price elasticities wrt fixed fee	-6.92	-5.33	-5.09	-4.78	-6.06
std.dev	1.29	1.44	0.78	1.10	0.91
mean own price elasticities wrt overage fee	-2.52	-2.26	-3.00	-2.40	-2.08
std.dev	0.78	1.08	1.42	1.12	0.33

Number of markets is the number of markets where a particular firm is present. The subscription price elasticity is defined as the percentage change in the penetration rate (the percentage of the population with mobile phones) in one market with a one percentage point increase in fixed fees of all plans in the market. A particular firm's price elasiticity in each market is computed as the percentage change in the firm's market share when the fixed fees of all plans offered by this firm in this market are increased by 1 percent, while holding prices of other firms constant. For example, Sprint was operating in 20 out of 26 markets in the estimation sample; if Sprint increases the fixed fee of all plans in one market by one percent while holding prices of other firms in the same market constant, the market share of Sprint would, on average (average across markets where this firm is present), decrease by seven percent.

Table 7: Estimates for costs

	Sprint	AT&T	Voicestream	Verizon	Cingular
number of markets	20	26	13	20	12
mean cost per customer $/mo	18.97	19.79	16.19	16.01	21.12
std.dev $/mo	5.36	6.59	8.55	5.14	4.77
Merrill Lynch: cost per customer $/mo	56.78	54.41	61.85	35.10	40.32
mean cost per minute $/min	0.12	0.10	0.09	0.12	0.11
std.dev $/mo	0.04	0.05	0.04	0.05	0.04
Industry estimate cost per minute $/min*	0.11				

The 2nd and 3rd rows of table 7 present the mean and standard deviation of cost per consumer of major mobile network operators across markets they served in the estimation sample. For example, Sprint served in 20 out of 26 markets in the estimation sample; the mean cost per consumer across these 20 markets is around $19, and the standard deviation of cost per consumer across these 20 markets is around $5. The 4th row of table 7 presents the Merrill Lynch measure of monthly operating cost per consumer reported in Merrill Lynch Global Wireless Matrix 2Q04. Merrill Lynch Global Wireless Matrix reports quarterly the estimates of monthly operating cost per consumer of major operators around world. The number reported in the last column of table 7 is the average of the 8 quarters in 2000-2001 reported in Global Wireless Matrix 2Q04 for major mobile network operators in US. The 5th and 6th row of table 7 present the mean and standard deviation of cost per minute of major mobile network operators across markets they served in the estimation sample. For example, Sprint served in 20 out of 26 markets in the estimation sample, the mean cost per minute across these 20 markets is around $0.12 and the standard deviation of cost per minute across these 20 markets is around $0.04.The last row of table 7 shows the costs per minute Sprint reported to FCC in the year 2003 in order to obtain a ruling from the FCC that it was entitled to seek reciprocal compensation based on its own wireless networks traffic-sensitive costs rather than the wireline carriers costs.[9]

Table 8: The effect of the "Bill Shock" regulation assuming no price adjustment

monthly per-household effect	before regulation with perception error	after regulation without perception error	change	% change
Non-welfare outcomes				
penetration of mobile	55%	59%	4%	7%
mean monthly calling minutes (cond on subscription) (min/mo)	115	144	29	25%
prob of using exactly free minutes in the plan (cond on subscription)	0.00	0.63	0.63	
prob of making overage payment (cond on subscription)	0.21	0.05	-0.16	-76%
mean prob of choosing small plans	0.42	0.48	0.06	14%
mean prob of choosing big plans	0.16	0.13	-0.03	-19%
mean monthly overage payment(cond on pay overage)	$24	$8	-$16	-67%
Welfare outcomes				
mean consumers surplus	$87	$98	$11	12%
mobile operators profit	$4	-$4	-$8	-200%
total surplus	$91	$94	$3	3%
monthly total effect				
Non-welfare outcomes				
number of hh with mobile	44 million	47 million	3 million	
total monthly calling minutes	8000 million	10000 million	2000 million	
number of hh making overage payment	11 million	3 million	-8 million	
monthly overage payment	$373 million	$33 million	-$340 million	
Welfare outcomes				
total consumers surplus	$6950 million	$7812 million	$862 million	
total mobile operators profit	$347 million	-$296 million	-$643 million	
total surplus	$7297 million	$7516 million	$219 million	

Table 8 presents the monthly per-household and total effect of the "Bill Shock" regulation, keeping the pricing structure unchanged. We first compute the monthly per-household effect in each market (defined as economic-year pair), then multiply the per-household effect in each market by the number of households reported in Census in the year 2000. The numbers reported are the sums of the total effects of the 26 markets in the estimation sample. The per household effect reported in table 8 is computed by dividing the total effect reported in the table by the total number of households in 26 markets in the estimation sample. The monetary values reported in Table 8 are in year 2000 dollars.

Table 9: Changes in fixed fees and overage fees after the "Bill Shock" regulation

	Sprint	AT&T	Voicestream (T-mobile)	Verizon	Cingular
number of markets	20	26	13	20	12
mean change in fixed fees	39%	40%	45%	43%	40%
mean change in overage fees	-61%	-57%	-62%	-58%	-63%
mean of minimum fixed fees before regulation ($/min)	28	22	22	22	24
mean of minimum fixed fees after regulation ($/min)	39	31	31	31	34
mean of cost per customer ($/mo)	19	20	16	16	21
mean of minimum overage fees before regulation ($/min)	0.36	0.28	0.23	0.30	0.35
mean of minimum overage fees after regulation ($/min)	0.14	0.12	0.09	0.12	0.13
mean of cost per minute ($/min)	0.12	0.10	0.09	0.12	0.11

Table 9 shows the changes in fixed fees and overage prices in the new price equilibrium.

Table 10: The effect of the "Bill Shock" regulation with adjusted prices

monthly per-household effect	before regulation with perception error	after regulation without perception error	change	% change
Non-welfare outcomes				
penetration of mobile	55%	48%	-7%	-13%
mean monthly calling minutes (cond on subscription) (min/mo)	115	135	20	17%
prob of using exactly free minutes in the plan (cond on subscription)	0.00	0.35	0.35	-
prob of making overage payment (cond on subscription)	0.21	0.42	0.21	100%
mean monthly overage payment(cond on pay overage)	$24	$12	-$12	-50%
Welfare outcomes				
mean consumers surplus	$87	$89	$2	2%
mobile operators profit	$4	$4	$0	0%
total surplus	$91	$93	$2	2%
monthly total effect				
Non-welfare outcomes				
number of hh with mobile	44 million	39 million	-5 million	
total monthly calling minutes	8000 million	8425 million	425 million	
number of hh making overage payment	11 million	22 million	11 million	
monthly overage payment	$373 million	$372 million	-$1 million	
Welfare outcomes				
total consumers surplus	$6950 million	$7110 million	$160 million	
total mobile operators profit	$347 million	$352 million	$5 million	
total surplus	$7297 million	$7452 million	$165 million	

The slight increase in the total industry profit $5 million is offset by the cost of notifying consumers. Assuming that mobile network operators have to call each household for one minute each month, then, with a cost per minute of $0.13, the slight increase in the total industry profit is completely offset.

Table 11: The per-household effect of the "Bill Shock" regulation with adjusted prices for different types of consumers

per household per month	before regulation with perception error	after regulation without perception error	change	% change
Consumer surplus				
first quartile	$0	$0	$0	0%
second quartile	$1	$0	-$1	-47%
third quartile	$51	$50	-$1	-1%
fourth quartile	$295	$306	$11	4%
Industry Revenue				
first quartile	$1	$0	$0	0%
second quartile	$2	$1	-$1	-44%
third quartile	$32	$33	$1	4%
fourth quartile	$56	$59	$3	5%
Penetration rate				
first quartile	2%	0%	-2%	-77%
second quartile	29%	13%	-16%	-55%
third quartile	91%	82%	-9%	-10%
fourth quartile	100%	100%	0%	0%
Monthly calling minutes (cond on subscription) (min/month)				
first quartile	31	37	6	19%
second quartile	62	73	11	18%
third quartile	103	123	20	19%
fourth quartile	267	307	40	15%

This table presents the mean change for consumers whose preference parameters θ_i are in a different quartile of the preference distribution. For consumers whose preference parameters are in the second and third quartiles of the preference distribution, the loss from the extensive margin (decrease in penetration rate) due to an increase in fixed fees surpasses the gain from the intensive margin (increase in monthly calling minutes) due to the decrease in overage fees. For consumers whose preference parameters are in the fourth quartile of the preference parameter, the increase in fixed fees has almost no impact on the extensive margin (no change in penetration rate), and the gain from the intensive margin (increase in monthly calling minutes) due to decrease in overage fees has a dominant effect.

A The proposed "Bill Shock" Regulation

The following text is taken from the section 3 of S. 732: Cell Phone Bill Shock Act of 2011: Notification of cell phone usage limits; subscriber consent.

(a) Definition- In this section, the term commercial mobile service has the same meaning as in section 332(d)(1) of the Communications Act of 1934 (47 U.S.C. 332(d)(1)).

(b) Notification of Cell Phone Usage Limits- The Federal Communications Commission shall promulgate regulations to require that a provider of commercial mobile service shall–

(1) notify a subscriber when the subscriber has used 80 percent of the monthly limit of voice minutes, text messages, or data megabytes agreed to in the commercial mobile service contract of the subscriber;

(2) send, at no charge to the subscriber, the notification described in paragraph (1) in the form of a voice message, text message, or email; and

(3) ensure that such text message or email is not counted against the monthly limit for voice minutes, text messages, or data megabytes of the commercial mobile service contract of the subscriber.

(c) Subscriber Consent- The Federal Communications Commission shall promulgate regulations to require a provider of commercial mobile service shall–

(1) obtain the consent of a subscriber who received a notification under subsection (b) to use voice, text, or data services in excess of the monthly limit of the commercial mobile service contract of the subscriber before the provider may allow the subscriber to use such excess services; and

(2) allow a subscriber to, at no cost, provide the consent required under paragraph (1) in the form of a voice message, text message, or email that is not counted against the monthly limit for voice minutes, text messages, or data megabytes of the commercial mobile service contract of the subscriber.

B Field Study Supporting the Model Assumption

To support the crucial assumption made in the model, we conducted a field study at a major university in North America. We asked people passing by a hot spot of the university during lunchtime to fill out a survey in exchange for a chocolate bar. On the first page of the survey, we asked respondents to estimate their current usage of voice, text and data during this monthly billing cycle. We then asked them to turn over the page and check their actual usage of voice, text and data this month, either from their phones or by logging on to their online account.

We collected 100 surveys from this field study. In the end, 86 respondents completed the information on estimated voice usage and actual voice usage; 82 completed the information on estimated text usage and actual text usage; 75 completed the information on estimated data usage and actual data usage. We define people's perception error as the ratio of their actual usage over their estimated (perceived) usage. The results presented here regarding respondents' perception error on voice, text and data usage come from surveys with completed information on estimated and actual usage of voice, text and data respectively.

Table A1 presents summary statistics of respondents' perception error on their voice usage, text usage and data usage. The table shows that the mean of perception error on voice, text and data is close to 1; i.e., on average, people have a correct perception about their real usage. Figure A1 presents the histogram of the perception error of respondents' voice, text and data usage from this field study. The figure shows that the distribution of respondents' perception error on their voice, text and usage resembles to a log-normal distribution.

C Details on the Empirical Industry Model

C.1 Details on Stage 3: Consumers' calling decision

C.1.1 Income effect and the preference parameter

a_i measures the marginal utility of income in the unit of one minute. We allow a_i to vary as a function of a household's monthly income per person: [10]

$$a_i = \bar{a} + a_D D_i^a. \tag{5}$$

The preference parameter θ_i measures how many minutes consumer i will call monthly if the marginal price of calling is zero. θ_i varies as a function of consumers' observable and unobservable characteristics. We restrict θ_i to be positive by specifying it as an exponential function of consumers' characteristics

$$\theta_i = exp(\bar{\theta} + \theta_D D_i + \nu_i), \tag{6}$$

where $\{\bar{\theta}, \theta_D\}$ are parameters and D_i is a column vector of consumers' key demographic characteristics.[11] ν_i represents consumers' unobservable heterogeneity. We assume that ν_i has a normal distribution with mean 0 and variance σ^2. As discussed in Berry et al. (1995), the observable and unobservable heterogeneity in θ_i ensures that consumers who have a strong preference for calls (high θ_i) will tend to attach high utility to all plans with large minutes allowances. This specification allows plans with similar minutes allowances to be close substitutes for each other.

C.1.2 Solution for the optimal perceived calling minute

The consumer's expected overage payment is given by $\int_\omega p_j \max\{x_i\omega - A_j, 0\}\, dF(\omega)$. ω follows a distribution with the probability density function $f(\omega)$ and the cumulative distribution function $F(\omega)$. Taking the derivative of the expected overage payment with respect to x_i, we can derive the expected marginal price of the next calling minute as follows.

$$\begin{aligned}
&\frac{\partial}{\partial x_i}\Big(\int_\omega p_j \max\{x_i\omega - A_j, 0\} dF(\omega)\Big) \\
&= \frac{\partial}{\partial x_i}\Big(p_j \int_{x_i\omega - A_j > 0} (x_i\omega - A_j) f(\omega) d\omega\Big) \\
&= \frac{\partial}{\partial x_i}\Big(p_j\Big(\int_{\omega > \frac{A_j}{x_i}} x_i \omega f(\omega) d\omega - A_j\big(1 - F\big(\frac{A_j}{x_i}\big)\big)\Big)\Big) \\
&= p_j \int_{\omega > \frac{A_j}{x_i}} \omega f(\omega) d\omega \\
&= p_j \frac{\int_{\omega > \frac{A_j}{x_i}} \omega f(\omega) d\omega}{\big(1 - F\big(\frac{A_j}{x_i}\big)\big)}\Big(1 - F\big(\frac{A_j}{x_i}\big)\Big) \\
&= p_j (E(\omega | x_{ij}\omega > A) prob(x_{ij}\omega > A))
\end{aligned}$$

The consumer's optimal choice is to equate expected marginal utility to expected opportunity cost for the next calling minute, as illustrated in Figure 1-b. Formally, we have

$$\underbrace{\frac{\theta_i}{x_{ij}}}_{\text{EMU for the next calling minute}} = \underbrace{a_i p_j (E(\omega | x_{ij}\omega > A) prob(x_{ij}\omega > A)) + 1}_{\text{Expected opportunity cost of the next calling minute}} \tag{7}$$

[10] monthlyincome per person $= \frac{\text{monthly income}}{\text{household size}}$, D_i^a is the high income dummy which equals to 1 if household i has monthly income per person higher than \$1000 per month.

[11] Consumers' key demographic characteristics include family dummy, the age of the head of the household is over 55 dummy, and renting dummy.

The solution for the optimal perceived calling minute x_{ij}^* can be obtained by numerically solving equation 7.

C.1.3 The impact of perception error on consumers' decision under two-part tariff

If consumer i is under a two-part tariff plan with monthly fixed fee of F_j and per minute price p_j, the existence of perception error does not change consumers' optimal calling minute and payment in expectation, it also does not change the utility consumer get from calling under plan j. To see this, note that with perception error, consumer i tries to choose the perceived optimal number of calling minute x_{ij} to maximize her expected utility conditional on the distribution of ω:

$$\max_{x_{ij}} v_{ij}(x_{ij}) = \int_\omega \overbrace{\theta_i ln(x_{ij}\omega)}^{\text{utility from calling}} + x_{i0} - \overbrace{a_i p_j x_{ij}}^{\text{disutility from payment}} dF(\omega). \tag{8}$$
$$\text{subject to} \quad \int_\omega (x_{ij}\omega)dF(\omega) + \underbrace{x_{i0}}_{\text{outside activity}} \leq \underbrace{T}_{\text{time constraint}}$$

Let x_{ij}^* be the optimal number of perceived minute. F.O.C implies that

$$\frac{\theta}{x_{ij}^*} - (1 + a_i p_j)\int_\omega \omega dF(\omega) = 0 \tag{9}$$

Because $\int_\omega \omega dF(\omega) = 1$, we obtain $x_{ij}^* = \frac{\theta}{1+a_i p_j}$.

Similarly, because $\int_\omega ln\omega dF(\omega) = 0$ and $\int_\omega \omega dF(\omega) = 1$, the utility consumer i gets from calling under plan j is

$$v(x_{ij}^*) = \theta_i ln\theta_i - \theta_i ln(1 + a_i p_j) - \theta_i + T \tag{10}$$

If Bill Shock regulation eliminates perception error for consumers under two-part tariff plans, consumer i chooses actual number of calling minute x_{ij}^B to maximize utility from calling under plan j

$$\max_{x_{ij}^B} v_{ij}(x_{ij}) = \overbrace{\theta_i ln x_{ij}^B}^{\text{utility from calling}} + x_{i0} - \overbrace{a_i p_j x_{ij}^B}^{\text{disutility from payment}} \tag{11}$$
$$\text{subject to} \quad x_{ij}^B + \underbrace{x_{i0}}_{\text{outside activity}} \leq \underbrace{T}_{\text{time constraint}}$$

Let x_{ij}^{B*} be the optimal number of calling minute. F.O.C implies that

$$\frac{\theta}{x_{ij}^{B*}} - (1 + a_i p_j) = 0 \tag{12}$$

we obtain $x_{ij}^{B*} = \frac{\theta}{1+a_i p_j}$. The utility consumer i gets from calling under plan j is

$$v(x_{ij}^{B*}) = \theta_i ln\theta_i - \theta_i ln(1 + a_i p_j) - \theta_i + T \tag{13}$$

It is easy to see that $E(x_{ij}^*\omega) = x_{ij}^{B*}$ and $v(x_{ij}^*) = v(x_{ij}^{B*})$.

C.2 Details on Stage 2: Consumers' subscription decision

We allow α_i to vary as a function of the household's monthly income per person.

$$\alpha_i = \bar{\alpha} + \alpha_D D_i^\alpha. \tag{14}$$

We assume that the utility from the outside option in market m is $T + \sigma_\epsilon \epsilon_{im0}$, which is the utility that consumers get by spending all of their time on outside activities. The interpretation of the utility that consumer i derives from plan j is the difference with respect to the above outside option. Note that T is subtracted out in the difference, and the mean utility from the outside option can be thought of as being normalized to zero. Given the distribution of utility function parameters and the plan's attributes in a given market, we can compute the model's predicted market shares by aggregating over utility-maximizing households.

Finally, for computational simplicity, we assume that the idiosyncratic errors ϵ_{ijm} have an i.i.d extreme value "double exponential" distribution. We denote the standard error of idiosyncratic errors to be σ_ϵ, which we estimate. Let F_i^m be the distribution of consumer preferences and demographics in market m. Given the distribution assumption on ϵ_{ijm}, the model's predicted market share for plan j in market m is:

$$s_{jm} = \int \{ \frac{exp((\delta_{jm} + \mu_{ijm})\sigma_\epsilon^{-1})}{1 + \sum_k exp((\delta_{km} + \mu_{ikm})\sigma_\epsilon^{-1})} \} dF_i^m, \quad (15)$$

where $\delta_{jm} = Z'_{jm}\lambda + \bar{\alpha} F_{jm} + \xi_j$ and $\mu_{ijm} = v(x^*_{ijm}; \theta_i, a_i, A_j, p_j) + (\alpha_i - \bar{\alpha})F_{jm}$. We aggregate the demand at the plan level. In the estimation, we take a "Micro BLP" approach and match the model prediction with the data both at the aggregate level-market shares and micro level-moments of monthly calling minutes.

C.3 Details on Stage 1: Mobile network operators' pricing decision

C.3.1 Details on the cost structure

For each mobile network operator f in market m, the total monthly cost (TMC) is defined as

$$TMC_{fm} = N_{cus} C_{fm} + N_{min} c_{fm} + FMC_{fm}, \quad (16)$$

where N_{cus} is the total number of consumers served by firm f in market m; N_{min} is the total number of calling minutes by all consumers of firm f in market m; C_{fm} is the cost of serving one consumer for firm f in market m; c_{fm} is the marginal cost per minute for firm f in market m; and FMC_{fm} is the fixed monthly operating cost that is not affected by the number of consumers served or the total monthly calling minutes.

D Details on the Estimation Strategy

D.1 Estimation Algorithm

For a given value of nonlinear parameters, $\{\alpha_D, \sigma_\epsilon, \bar{\theta}, \sigma, \sigma_\omega, \bar{a}, a_D, \theta_D\}$, I construct the model prediction on monthly calling minutes and on the market share of plans.

Step 1: Simulate the preference parameter θ_{im} for each simulated consumer i in market m.

I simulate $i = 1, 2, \ldots, N_m$ in $m = 1, 2, \ldots, M$ markets. The demographics of each simulated consumer D_{im} in market m are drawn from the observations in the corresponding market in the national survey data. I also draw one realization of usage shocks ν_{im} for each simulated consumer from the assumed distribution (normal with mean 0 and variance σ^2). Each simulated consumer i's calling preference θ_{im} is computed according to equation (6).

Step 2: Given the preference parameter θ_{im} for each simulated consumer i in market m, compute consumer i's perceived optimal usage under plan j, x^*_{ij}; compute the utility each simulated consumer i gets from plan j and the model prediction on the market share of plans.

Consumer i's perceived optimal usage under plan j, x^*_{ij}, can be obtained by solving equation (7). Then, the utility each simulated consumer i gets from plan j is computed using equation (3). The model prediction on each plan's market share can then be computed using equation (15).

Step 3: Find the value of δ_{jm} which equates observed market shares with predicted market shares using the contraction mapping from Berry et al. (1995); given δ_{jm}, recover the model's prediction on the probability of consumer i choosing plan j in market m, $\hat{s}_{ijm}$; use $\hat{s}_{ijm}$ as a weighting measure to construct moments of the model predicted monthly calling minutes conditional on plan choices and subscribing to mobile phones;

construct moments used in the estimation by taking the difference between the model predicted moments and the moments in the data.

Construction of moments in the estimation Let $\hat{p}_{ijm} = \sum_{j=1}^{N_{Jm}} \hat{s}_{ijm}$ be the probability of subscribing to mobile phones for consumer i in market m; the moments used in estimation can be constructed as follows:

$$M_1 = \sum_{m=1}^{M} \frac{n_m}{n}\Big\{\frac{1}{N_m}\sum_{i=1}^{N_m}\{\sum_{j=1}^{N_{Jm}} Pr(0.9 \leq \frac{x^*_{ijm}\omega}{A_{jm}} \leq 1.1)\hat{s}_{ijm}\}\hat{p}^{-1}_{ijm}\Big\} - p_{ur} = 0$$

$$M_2 = \sum_{m=1}^{M} \frac{n_{md}}{n_d}\Big\{\frac{1}{N_{md}}\sum_{i=1}^{N_{md}}\{\sum_{j=1}^{N_{Jm}} E_\omega(x^*_{ijm}\omega)\hat{s}_{ijm}\}\hat{p}^{-1}_{ijm}\Big\} - \bar{x}_d = 0$$

$$M_3 = \frac{((\frac{n}{n-1})\sum_{m=1}^{M}\frac{n_m}{n}\Big\{\frac{1}{N_m}\sum_{i=1}^{N_m}\{\sum_{j=1}^{N_{Jm}} E_\omega(x^*_{ijm}\omega - \hat{\bar{x\omega}})^2\hat{s}_{ijm}\}\hat{p}^{-1}_{ijm}\Big\})^{\frac{1}{2}}}{|\hat{\bar{x}}|} - \frac{\sigma_x}{|\bar{x}|} = 0$$

$$M_4 = \frac{\sum_{m=1}^{M}\frac{n_{mI}}{n_I}\Big\{\frac{1}{N_{mI}}\sum_{i=1}^{N_{mI}}\{\sum_{j=1}^{N_{Jm}} E_\omega(x^*_{ijm}\omega - \hat{\bar{x_I}\omega})(p_{jm} - \bar{p})\hat{s}_{ijm}\}\hat{p}^{-1}_{ijm}\Big\}}{\hat{\sigma}_{x_I}\hat{\sigma}_p} - \rho_{x_I p} = 0$$

$$M_5 = \sum_{m=1}^{M} \frac{N_{Jm}}{N_J}\Big\{\frac{1}{N_{Jm}}\sum_{j=1}^{N_{Jm}} \xi_{jm} Z^d_{jm}\Big\} = 0$$

$M_1 - M_5$ are five sets of moment conditions used in the estimation: (1) the probability that the monthly calling minutes fall in between 90% and 110% of the allowance; (2) the mean of monthly calling minutes for the eight combinations of three demographic groups (family, age, and rent); (3) the coefficient of variation in monthly calling minutes; (4) the correlation of the monthly calling minutes with the overage price of the plan chosen by the two income levels; (5) the covariance of demand-side instruments, Z^d_{jm}, with the unobserved demand shock ξ_{jm}. On the left hand side are moments from the model prediction, and the corresponding moments in the data are on the right-hand side. For the first four sets of moments, the model prediction is constructed as the weighted average of the average per market using the number of observations per market in the data as weight (n_m is the number of observations in market m in the data, and n is the total number of observations in the data); the average in each market is computed by averaging the weighted average of each simulated individual (using the probability of each individual choosing a particular plan ($\hat{s}_{ijm}$) conditional on choosing mobile phone services ($\hat{p}^{-1}_{ijm}$) as weights). N_m is the number of simulated individuals in market m. For the moment (1), given the parametric assumption on the distribution of the usage error ω, $Pr(0.9 \leq \frac{x^*_{ijm}\omega}{A_{jm}} \leq 1.1)$ is computed using $F(1.1\frac{A_{jm}}{x^*_{ijm}}) - F(0.9\frac{A_{jm}}{x^*_{ijm}})$ where F is the cumulative distribution function of ω. For the moment (2), n_{md} is the number of observations in the demographic group d in market m in the data, n_d is the total number of observations in the demographic group d in the data and N_{md} is the number of simulated individuals in the demographic group d in market m. For the moment (4), n_{mI} is the number of observations in the income level I in market m in the data, n_I is the total number of observations in the income level I in the data and N_{mI} is the number of simulated individuals in the income level I in market m.

Table A1: Summary Statistics of the Perception Error from Field Study

	Number of obs	Mean	Std	Min	Max
Voice	86	0.96	0.83	0	3.8
Text	82	1.17	1.10	0	5
Data	75	0.91	0.69	0	3.3

Table A1 presents summary statistics of respondents' perception error on their voice usage, text usage and data usage.

Figure A1: Histogram of Perception Error of Voice, Text and Data Usage from Field Study

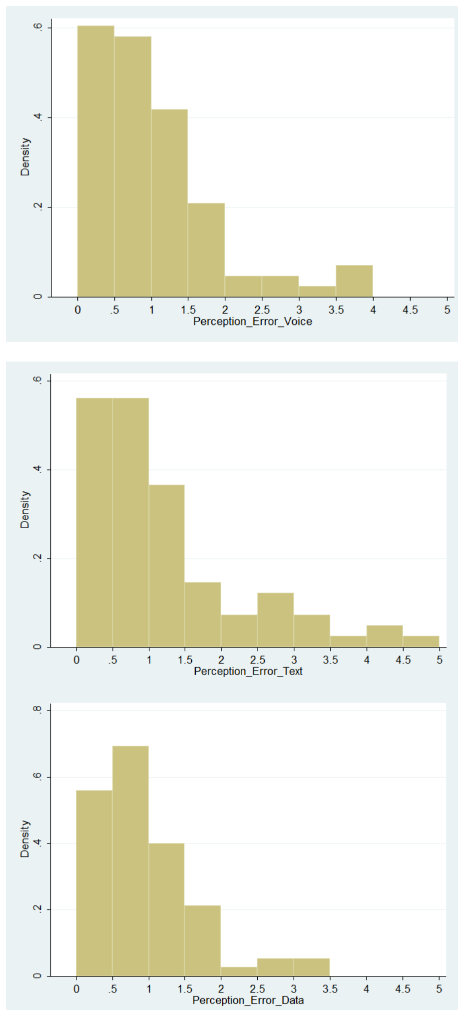


Figure A1 shows the distribution of respondents' perception error on their voice, text and usage.