The Welfare Effects of "Bill Shock" Regulation in Mobile Telecommunication Markets*

Lai Jiang †

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Abstract

I study the welfare 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 data set, I estimate an industry model of calling, subscription and pricing. My counterfactual simulations predict that the proposed regulation has two conflicting welfare effects: a positive effect from lower overage prices and a negative effect from higher fixed fees. In net terms, I predict a 2% increase in consumer surplus, while industry profit remains constant. Moreover, the regulation benefits heavy users and hurts light users.

Keywords: Bill Shock, Three-part tariff, Price uncertainty

JEL codes: $L13$, $L50$, $L96$

1 Introduction

A recent survey conducted by the Federal Communications Commission (FCC) finds that, in 2010, one in six mobile phone users has experienced "Bill Shock", an unexpected increase in their monthly mobile phone bill. Concern with this phenomenon led to a proposed "Bill Shock" regulation. This regulation 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

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†Leonard Stern School of Business, NYU. 44 W4th St, New York, NY10012. E-mail: ljiang@stern.nyu.edu

fee, a monthly allowance of free calling minutes, and an overage price per minute.).[1] The proposed Bill Shock regulation reflects an important dimension of consumer protection policies: the reduction of consumer price uncertainty. By estimating the welfare effects of Bill Shock regulation, this paper is one of the first to contribute to understanding the welfare effects of consumer protection policies that attempt to reduce consumer price uncertainty.

Using a rich billing data set, I estimate an industry model of calling, subscription and pricing. The industry model has three stages: first, mobile network operators decide the pricing structure of mobile phone plans; second, consumers make subscription decisions on whether to use mobile phones and which plan to use; third, consumers make consumption decisions conditional on the plan chosen. I jointly estimate the consumers' preference for usage and subscription of mobile phone services. I then back out the mobile network operators' marginal cost using the demand estimates and the optimal pricing condition. Given these estimates, I simulate the price and quantity changes in the counterfactual scenario where the proposed regulation is implemented.

A crucial step in my estimation is to identify consumer price uncertainty. My 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, which is informative about the degree of consumer price uncertainty.

I 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; instead, they recall previous usage with an error. The presence of the perception error can be interpreted as limited consumer attention in keeping track of the exact usage. In this sense, my paper relates to the recent "behavior" industrial organization literature that incorporates bounded rationality into agents' decision process. See Ellison (2006) for a discussion and additional references.

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

[1] The FCC and mobile network operators reached a new bill shock agreement in October 2011. By April 2013, this agreement commits mobile network operators to alert consumers when they approach and exceed their included voice, text, and data allowances. The proposed regulation has been delayed while the FCC monitors the industry's voluntary compliance under the new agreement.

change after the price adjustment.

I estimate that mobile network operators would lose \$650 million per month, which is 33% of the industry revenue, from Bill Shock regulation assuming no price adjustment. 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; (2) loss in fixed fees due to consumer switching from plans with big allowance to plans with small allowance.

Allowing for the price adjustment, I predict that fixed fees would be increased and overage prices would be decreased.[2] The price adjustments made by mobile network operators have two conflicting effects: (1) on the extensive margin, the increase in fixed fees leads to a decrease in the penetration rate from 55% to 48% and to a loss in welfare; (2) on the intensive margin, the decrease in overage prices leads to an increase in monthly calling minutes from 115 to 134 minutes per household and to a gain in welfare. The welfare gain from the intensive margin exceeds the welfare loss from the extensive margin, resulting in a positive welfare effect. This gain is captured by consumers (\$2 per household per month in year 2000 dollars, i.e. 2% increase), while the industry profit does not change.

I also find that the proposed Bill Shock regulation imposes an important distributional effect on consumer surplus: the increase in fixed fees and decrease in overage prices has different implications for different types of consumers. For light users of mobile phones, the loss due to higher fixed fees surpasses the gain due to lower overage prices. In contrast, for heavy users, the increase in fixed fees has almost no impact on the penetration rate, and the gain due to lower overage prices dominates.

Section 2 discusses related literature. Section 3 describes data. Section 4 describes the model. Section 5 discusses identification and estimation of parameters in the model. Section 6 presents estimation results. Section 7 discusses the welfare effects of Bill Shock regulation via counterfactual simulations. Section 8 concludes.

2 Related Literature

In this paper, I model consumer price uncertainty by including a perception error in consumers' consumption decisions, that is, I assume consumers have limited ability to recall previous usage. In this sense, my paper is related to the "behavior" IO literature that incorporates bounded rationality into agents' decision process. See Ellison (2006) for a discussion of bounded rationality in industrial organization. Related applied work

[2]This is consistent with what happened to the banking industry after the implementation of "Overdraft Protection" regulation: banks lost billion of dollars after the initial implementation of the regulation in July, 2010; and in response to that, the banking industry moves towards increasing the annual fee for checking accounts (See "Bank service fees fall \$1.6 billion after new overdraft regulations" By Max Thompson June 30th, 2011).

includes DellaVigna & Malmendier (2004), Ellison (2005), and Gabaix & Laibson (2006).

Complementary theoretical work by Grubb (2011) shows that the welfare effects of Bill Shock regulation are ambiguous. Complementary empirical work by Grubb & Osborne (2012) predicts that the regulation will lower average consumer welfare by about $2 per year.

The data used in Grubb & Osborne (2012) 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 (2012) from addressing the 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 address the distributional effect of Bill Shock regulation on different types of consumers, which turns out to be more substantial than the average welfare effect.

The panel nature of data in Grubb & Osborne (2012) allows them to address consumers' beliefs and learning: 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.

I use the absence of bunching at the kink points of the three part tariff plans to demonstrate that consumers do not know exactly when they use up their allowance. Similar issues on taxpayers' behavior have been studied by Saez (2010). The absence of bunching at tariff kink points in electricity has also been found in Borenstein (2009).

I model consumers' limited ability to recall previous usage. This key feature of consumer calling model is related to the recent literature on limited consumer attention: for example, Stango & Zinman (2011) explore the dynamics of limited attention in the market for checking overdrafts.

My counterfactual simulations study the effects of providing consumers with more information on their mobile phone usage. This feature is related to the economics literature on the effect of providing consumers with more information: for example, Jin & Leslie (2003) examine the effect of an increase in product quality information to consumers on firms' choices of product quality in the context of restaurant hygiene grade cards; Handel (2010) studies the welfare impact of an information provision policy that nudges consumers toward better decisions by reducing switching costs in health insurance markets; Bollinger et al. (2011) study the impact of mandatory calorie posting on consumers' purchase decisions.

The price adjustment studied in my counterfactual simulations relates to the literature on nonlinear pricing including Armstrong & Vickers (2001), Grubb (2009), Miravete (1996), Oi (1971), Rochet & Stole (2002), and Stole (2007).

Finally, I study the mobile phone industry in this paper. For this reason, my paper is related to the literature on the mobile phone industry including Busse (2000), Hausman (1999), Huang (2008), Iyengar et al. (2007), Miravete & Röller (2004), Rodini et al. (2003), Seim & Vaiard (2011), and Yao et al. (2011).

3 Data

The main data source of this paper comes from the bill harvesting data collected by TNS Telecoms. Previous studies that have used data from TNS include Rodini et al. (2003) and Economides et al. (2008).

3.1 TNS national survey

TNS conducts a quarterly national survey of U.S. households. The sample used in the paper includes the years 2000-2001, hence 8 quarters in total. This historical nature of data has the several advantages: (1) In 2000-2001, the voice was the major function of mobile phones, which provides a cleaner setting to focus on the voice usage of mobile phones only; (2) Mobile phones were more homogenous in 2000-2001 than 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.[3] Naturally, the older a dataset is, the more difficult it is to apply it to current issues. That said, the study based on the 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 the survey, TNS asks about households' characteristics, and the ownership of mobile phones. Among 263,707 observations appearing in the survey in 2000-2001, 262,826 of them have complete key demographic information.[4] Among these 262,826 households, 130,259 (50%) of them own at least one mobile phone. Table 1 compares the mean of key dummy variables in different consumer samples in TNS data. From table 1, it is clear that households that own at least one mobile phone are more likely to be a family than the general population.[5] The head of the household also tends to be younger for households with mobile phones than in the general population. Finally, households with mobile phones are less likely to rent than in the general population.

[3]50% of households had mobile phones, and the majority of them (60%) only had one mobile phone.

[4]145,543 households appear only once, 52,901 households appear twice and 3,827 households appear three times during the 8 quarters in 2000-2001.

[5]Family is defined as the size of household is bigger than 1.

Among 130,259 households with mobile phones in the TNS national survey sample, 16,914 of them provide their mobile phone bill.[6] Table 1 compares the key demographic information of two groups: households with mobile phones with households who provided bills. Key differences include older people are more likely to provide bills and people who rent are less likely to hand in bills.

3.2 TNS mobile phone bills

As mentioned in the previous section, around 16% of househoulds in TNS national survey handed in their mobile phone bills. There are in total 17,155 mobile phone bills; I call this the bill data. In a separate file, 11,051 bills have detailed information on each outgoing call and incoming call during the month; I call this the call detail data. Bill data can be uniquely matched with call detail data using quarter-household ID-bill number.

In the bill data and call detail data, I can see the mobile operator chosen by the household. Table 2 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 reports the aggregate market shares reported in Kagan's Wireless Telecom Atlas & Databook 2001 Volume 2. I find that the bill data and call detail data are representative with few exceptions.[7]

Table 3 shows the summary statistics of key variables included in the bill data. The bill data has two shortcomings. First, billed minutes reported in the bill data do not distinguish minutes that are charged because of overage prices (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.[8] Second, 4,057 bills recorded zero usage, which is inconsistent with the call detail data. Call detail data overcomes these shortcomings.

The 11,051 bills with call detail information record in total 748,391 calls. For each call, I can see the time of the call, whether it is roaming, how much charges apply to this call, and how much long distance charges apply to this call. 111,148 calls were charged strictly positive price outside of the allowance, which

[6] There are in total 17,155 mobile phone bills in the raw data, 241 households with bills cannot be matched with the national survey sample.

[7] 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 is only established at the beginning of the year 2001 as a joint venture between SBC Communications and BellSouth; the bill level data only have 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.

[8] In the data period, year 2000-2001, mobile network operators billed consumers in addition to the monthly fixed fee according to two major different sources: the first source was the usage outside of the allowance level of the three-part tariffs; the second source came from roaming calls and long distance calls which are not included in the allowance for local and regional plans. In year 2000-2001, major operators offered three type of plans: local plan, regional plan, and national plan. National plan includes long distance calls and roaming calls in the allowance. Local and regional plans usually do not include roaming and long distance calls in the monthly allowance.

I call billed calls. Table 3 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, I can overcome shortcomings in bill data discussed above: I can compute how many billed minutes are due to overage prices (additional minutes that are over the allowance), how many billed minutes are roaming minutes, and how many are long distance minutes. Finally, by adding the duration of all calls placed together, I can get the total number of minutes used.

Table 3 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.[9]

One limitation in the data is its cross sectional nature. U.S. mobile operators require consumers to sign up for a one-year or two-year contract subject to an early termination fee.[10] In the data, I can only see the bill of one month's usage for most households, and I do not have any information on the phone subsidy associated with the contract. I also do not know when households signed the contract with their operators.[11] However, my focus is on consumers' plan choices and usage decisions under three-part tariffs, not the long-term contract and phone subsidy.[12]

3.3 Tariff data

MyRatePlan.com collects pricing plans charged by different mobile operators.[13] I use tariffs offered by the same period as the sample period (year 2000-2001) of the bill data to construct the choice set of consumers in each market.[14]

Table 4 lists the plans offered by AT&T in New York at January, 2001. A plan is uniquely defined by five key characteristics: monthly fixed fee, allowance, overage price, long distance price, and roaming price. The plan's coverage is directly associated with the long distance price and roaming price: local plans charge

[9]This paper focuses on the impact of "bill shock" regulation on overage charges that are due to usage outside of the allowance but not due to roaming and long-distance calls which were initially not included in the allowance for local and regional plans. I model free roaming and free long-distance calls as two key characteristics of tariff plans which can distinguish national plans from regional plans and local plans. More recently, since all plans are changed to national plans, roaming and long-distance calls are less a problem for mobile phone users except for international roaming. Alerting consumers about the international roaming is also part of the "bill shock" regulation; I am not addressing this aspect in this paper.

[10]In U.S., prepaid cards are not as common as in Europe. 85% of consumers in the data) had contracts with the cell phone provider.

[11]Two major operators (Verizon and Cingular) were founded during the data period: Verizon started operating in May 2000, and Cingular started operating in January 2001. I assume that households with bills in 2000 made their plan choice in May 2000 and households with bills in 2001 made their plan choice in January 2001.

[12]It is less a problem for the data period (year 2000-2001), since mobile phones were mainly used for calling, smart phones did not exist yet, and mobile phones were more homogenous than today.

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

[14]Special thanks to Allan Keiter from MyRatePlan.com for providing this historical data.

a strictly positive price for both long distance calls and roaming calls; regional plans offer free long distance calls and charge strictly positive price for roaming calls; national plans offer free long distance and roaming calls.

3.4 Estimation Sample

Please refer to the Appendix for the data matching process and the construction of the estimation sample. Table 6 shows the summary characteristics of key variables of aggregate level and micro level data in the estimation sample. Table 7 presents the number of bills with popular plans: the two most popular plans have 200 free minutes and 250 free minutes, respectively. The middle column of table 7 also shows the number of bills that have used more than the plan's monthly allowance, the last column shows the percentage of bills that have used more than the plan's monthly allowance.

3.5 Lack of bunching in the data

Under a three-part tariff, the marginal price changes discontinuously at the allowance point. For example, if a consumer chooses a plan with a \$29.99 monthly fixed fee, a 250 minutes of monthly allowance, and \$0.30 per minute of overage price, then: the marginal price of the next calling minute is zero if the usage is below 250 minutes, \$0.30 otherwise. Under the assumption that the distribution of consumer preferences for calling is smooth, if consumers were aware of their exact usage, a mass point of consumers would use exactly their monthly allowance.[15]

Figure 1 shows the histogram of the usage ratio in the data. The usage ratio is defined as the ratio of monthly calling minutes over the free minutes included in the plan: for example, a consumer who calls 90 minutes a month using a plan with 120 free minutes would have a usage ratio equal to $\frac{90}{120} = 0.75$. Bunching at the point where the marginal price changes discontinuously would appear as a spike at the usage ratio 1. From figure 1, it is clear that such bunching does not appear in the data, which is informative about the degree of consumer price uncertainty.

4 Industry Model

The value of imposing structure from an economic model on the data is that the structure can be used to infer the underlying distributions of valuations from the observed usage. This allows a wide range of

[15]See appendix for more details on why price discontinuity should generate bunching.

questions to be asked that are not possible without a model, such as: what would happen to the welfare of consumers if they knew exactly when they had reached their allowance? What would happen to the profit of mobile network operators if consumers were perfectly informed of the marginal price of the next calling minute?

The industry model predicts consumers' demand for mobile phone services, consumers' calling decisions conditional on subscribing to a mobile phone plan, and the pricing structure of plans offered by mobile network operators.

This section derives those predictions in terms of a variable set of parameters. The next section, on identification, estimation, and inference, picks a particular set of parameters so that the predictions from the model align with their empirical counterparts.

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

4.1 Consumers' calling decision

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

Consumer i faces a time constraint T. She chooses to allocate the time to talk on the mobile phone or to spend on her outside activity (the marginal utility of which is normalized to 1) subject to the time constraint T. Conditional on choosing plan j, consumer i chooses the quantity of calling minutes x_{ij} and the quantity of time spent on the outside activity x_{i0} to maximize her expected surplus:

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

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

θ_i is the preference parameter which measures how many minutes consumer i will call monthly if the marginal price of calling is zero; a_i measures the marginal utility of income.

4.1.1 Discussion of the perception error

Under a three-part tariff, the marginal price changes discontinuously at the allowance point. 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. Therefore, the lack of bunching in the data at the point where the marginal price changes discontinuously is informative about the degree of consumer price uncertainty.

I 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; they recall previous usage with an error instead. The presence of the perception error can be interpreted as limited consumer attention in keeping track of the exact usage. Under this specification, consumers' perceived usage is x_{ij} while the actual usage is $x_{ij}\omega$. Since ω is not observed, consumers maximize their expected utility conditional on the distribution of ω.

I assume that ω follows a log normal distribution with parameters μ and σ_ω, the mean and standard deviation of ω's natural logarithm.[16] I 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 $\mu = \frac{-\sigma_\omega^2}{2}$.

The consumer's expected overage payment is given by $\int_\omega p_j \max\{x_i\omega - A_j, 0\}\, dF(\omega)$. In the appendix, I show that, given that $F(\omega)$ is lognormal, the expected marginal price is $p_j(E(\omega|x_{ij}\omega > A)prob(x_{ij}\omega > A))$.[17] The consumer's optimal choice is to equate expected marginal utility to expected opportunity cost for the

[16] By definition, the variables logarithm is normally distributed.

[17] The expected marginal price is increasing within the monthly billing cycle as demonstrated in Figure 2. 80% of consumers have fewer total number of calling minutes in week 4 than in week 1. This provides the evidence that consumers do make their consumption decision based on an increasing perceived marginal price. In other words, consumers are myopic instead of being forward looking.

next calling minute, as illustrated in Figure 2. Formally, we have

$$\underbrace{\frac{\theta_i}{x_{ij}}}_{\text{EMU for the next calling minute}} = \underbrace{a_i p_j (E(\omega|x_{ij}\omega > A) prob(x_{ij}\omega > A)) + 1}_{\text{Expected opportunity cost of the next calling minute}} \tag{2}$$

Let x^*_{ij} be the value of x_{ij} that solves equation 2. 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

$$v_{ij}(x^*_{ij}; \theta_i, a_i, A_j, p_j) = \int_\omega \theta_i ln(x^*_{ij}\omega) - a_i p_j \max\{(x^*_{ij}\omega) - A_j, 0\} + T - (x^*_{ij}\omega) dF(\omega) \tag{3}$$

4.1.2 Income effect and the preference parameter

As mentioned earlier, a_i measures the marginal utility of income in the unit of one minute. I allow a_i to vary as a function of household's monthly income per person: [18]

$$a_i = \bar{a} + a_D D^a_i \tag{4}$$

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

$$\theta_i = exp(\bar{\theta} + \theta_D D_i + \nu_i) \tag{5}$$

where $\{\bar{\theta}, \theta_D\}$ are parameters and D_i is a column vector of consumers' key demographic characteristics.[19] ν_i represents consumers' unobservable heterogeneity. I assume 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 large plans. This specification allows plans with similar levels of allowance to be close substitutes for each other.[20]

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

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

[20] Each household is observed only once in the data used in this paper. If the panel data that tracks the same individual over time were available, it would be more desirable to take into account that consumers do not know their exact preference for calling in the following billing period; instead, they commit to a tariff based on their expected usage and their typical month-to-month

4.2 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. I assume that the total monthly utility consumer i enjoys from subscribing to plan j in market m is:

$$u_{ijm} = v(x^*_{ijm}; \theta_i, a_i, A_j, p_j) + Z'_{jm}\lambda + \alpha_i F_{jm} + \xi_{jm} + \sigma_\epsilon \epsilon_{ijm} \tag{6}$$

where $v(x^*_{ijm})$, defined as in equation 3, is the maximum monthly utility from calling 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.[21] I allow α_i to vary as a function of the household's monthly income per person.[22]

$$\alpha_i = \bar{\alpha} + \alpha_D D_i^\alpha \tag{7}$$

I assume that the utility from the outside option in market m is $T + \epsilon_{im0}$, which is the utility consumers get by spending all of their time on the outside activities. The interpretation of the utility consumer i derives from plan j is the difference with respect to the above outside option.[23] Given the distribution of utility function parameters and the plan's attributes in a given market, I can compute the model's predicted market shares by aggregating over utility maximizing households.

I introduce some commonly used notation which will make the expressions more compact:

$$\delta_{jm} = Z'_{jm}\lambda + \bar{\alpha} F_{jm} + \xi_j$$

where $\bar{\alpha} = \int \alpha_i$, and

$$\mu_{ijm} = v(x^*_{ijm}; \theta_i, a_i, A_j, p_j) + (\alpha_i - \bar{\alpha}) F_{jm}$$

so that

$$u_{ijm} = \delta_{jm} + \mu_{ijm} + \sigma_\epsilon \epsilon_{ijm}$$

variation in usage. A similar approach that addresses consumers uncertainty over future usage in an environment of temporally separated tariff and consumption choices has been taken by Miravete (2002) and Narayanan et al. (2007) under two-part tariff and Lambrecht et al. (2007) under three-part tariff.

[21] I include dummy variables for plan j's characteristics independent of monthly allowance such as year, firm, whether roaming minutes are included in the monthly allowance and whether long distance minutes are included in the monthly allowance.

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

[23] Note that T is subtracted out in the difference, the mean utility from the outside option can be think of being normalized to zero.

Finally, for computational simplicity, I assume that the idiosyncratic errors ϵ_{ijm} have an i.i.d extreme value "double exponential" distribution. I denote the standard error of idiosyncratic errors to be σ_ϵ, which I estimate.[24] Let F_i^m be the distribution of consumer preferences and demographics in market m. Given the distribution assumption on ϵ_{ijm}, the model predicted market share for plan j in market m is:

$$s_{jm} = \int \{ \frac{exp((\delta_{jm} + \mu_{ijm})\sigma_\epsilon^{-1})}{1 + \sum_k exp((\delta_{km} + \mu_{ikm})\sigma_\epsilon^{-1})} \} dF_i^m. \tag{8}$$

4.3 Mobile network operators' pricing decision

Mobile network operators compete by choosing plans' the pricing structures to maximize profits.

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

$$\pi_{fm}(\overrightarrow{F_m}, \overrightarrow{A_m}, \overrightarrow{p_m}, \overrightarrow{J_{fm}}) = \sum_{j \in \overrightarrow{J_{fm}}} s_{jm}(\overrightarrow{F_m}, \overrightarrow{A_m}, \overrightarrow{p_m}, \overrightarrow{J_{fm}})(F_j - C_{fm} \tag{9}$$
$$+ \int_i \{ \int_\omega p_j \max\{x_i^* \omega - A_j, 0\} - c_{fm}(x_i^* \omega) \; dF(\omega) \} dP_{ijm}(s_{ijm}, s_{jm}))$$

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 corresponding list of monthly fixed fees $\overrightarrow{F_m} = \{F_{jm}\}_j$, allowances $\overrightarrow{A_m} = \{A_{jm}\}_j$, and overage prices $\overrightarrow{p_m} = \{p_{jm}\}_j$; 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; dP_{ijm} is the distribution of consumers conditional on choosing plan j in market m.[25]

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 price. In the counterfactual analysis, I allow the mobile network operators to re-optimize their pricing strategy in response to the 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 prices, Lp, keeping all of the other components in the pricing structure unchanged (that is, the number of plans and allowances included in each plan are kept unchanged). For example, if the mobile network operator f decides to increase the level of fixed fees LF in market m by 20%, this means that the fixed fees of all plans offered by this mobile network operator f

[24] Typically this variance term is not identified separately, see Berry and Pakes (2007) for detail. Since units of utility are chosen with the calling data, in my setting this variance term is identified.

[25] The integral over individuals is the weighted sum of individuals where the weight of each individual i is the ratio of the probability of this individual choosing plan j, s_{ijm} over the market share of plan j, s_{jm}.

in market m would be increased by 20%. Similarly, if mobile network operator f decides to decrease the level of overage prices Lp in market m by 20%, it means that the overage prices of all plans offered by this mobile network operator f in market m would be decreased by 20%. Under this restriction, a mobile network operator f's profit in market m before fixed costs can be expressed as

$$\pi_{fm}(LF_{fm}, Lp_{fm}) = \sum_{j \in J_{fm}} s_{jm}(F_m(LF_{fm}), A_m, p_m(Lp_{fm}), J_{fm})(F_j(LF_{fm}) - C_{fm} \quad (10)$$
$$+ \int_i \{ \int_\omega p_j(Lp_{fm}) \max\{x_i^* \omega - A_j, 0\} - c_{fm}(x_i^* \omega) \, dF(\omega)\} dP_{ijm}(s_{ijm}, s_{jm}))$$

4.3.1 The cost structure

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

$$TMC_{fm} = N_{cus}C_{fm} + N_{min}c_{fm} + FMC_{fm} \quad (11)$$

where N_{cus} is total number of consumers served by firm f in market m; N_{min} is 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 nor the total monthly calling minutes.

The cost of serving one consumer includes the cost of customer service, billing, etc. If the demand for a given networks minutes exceeds the networks capacity, then some calls need to be dropped. I model the networks per-minute cost as including the shadow cost implicit in optimization with capacity constraints and demand uncertainty.

5 Identification and Estimation

In this section, the model developed in section 4 is estimated.

5.1 The estimation of consumers' preference parameters

I first estimate the distribution of preferences for calling on mobile phones, θ_i, the distribution of usage errors ω, using individual calling data; jointly with price coefficients, a_i and α_i, non-price preference parameters λ_j, using market share, price, and plan characteristics data. I jointly estimate a parameterized distribution of preferences for calling, θ_i with a parameterized distribution of usage errors, ω, the price coefficients, a_i and α_i, and the non-price preference parameters, λ_j.

Consumer i's monthly calling minutes on plan j, x_{ijm}, is obtained by solving equation 2; x_{ijm} hence depends on the calling preference, θ_i, the price coefficient,a_i, the distribution of perception error, $F(\omega)$, the monthly allowance of plan j, A_j, and the overage price of the plan j, p_j. The calling data are the measurement of monthly calling minutes at the individual level. I estimate the distribution of θ_i, a_i and ω by matching moments of the model prediction on monthly calling minutes to moments in the calling data.

Recall that consumers make a choice of plan based on the preference parameter θ_i, which is fully observed by consumers but not fully by the econometrician. For this reason, when observing consumption patterns I need to take into account the bias created by selection into plans. I correct for this selection bias by constructing moments of the model prediction on monthly calling minutes conditional on plan choices and subscribing to mobile phones. The conditioning on plan choices requires knowing parameters from the model of plan choices (stage two in the model, given in equation (6)). I jointly estimate the parameters of the distribution of calling preferences, marginal utility of income, and usage errors together with the plan choice parameters as in Lee (2010).

5.1.1 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 (12).

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 (2). Then, the utility each simulated consumer i gets from plan j is computed using equation (6). The model prediction on each plan's market share can then be computed using equation (8).

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.

Five sets of moment conditions are 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}. Please refer to Appendix for more details on the construction of moment conditions.

5.1.2 Identification of the distribution of the perception error

Recall that in the model, the perception error ω is unobservable to consumers at the consumption stage and smoothes out the marginal price consumers face. To implement the estimation of model parameters, I assume that ω follows the log normal distribution with parameters μ and σ_ω which are the mean and standard deviation of ω's natural logarithm. In addition, to ensure that consumers have on average correct perception of their actual usage level, i.e., $E(x_{ij}\omega) = x_{ij}E(\omega) = x_{ij}$, I impose the restriction that $\mu = -\frac{\sigma^2_\omega}{2}$, making $E(\omega) = e^{\mu + \frac{\sigma^2_\omega}{2}} = e^0 = 1$. Hence, the parameter σ_ω determines the distribution of the perception error ω.

The parameter σ_ω is sensitive to the moment (1), the probability that the monthly calling minutes fall in between 90% and 110% of the allowance level. When σ_ω is close to zero, i.e., consumers have precise perception of their actual usage, a large proportion of consumers would end up using between 90% and 110% of the allowance because of the discontinuity in the marginal price. The larger the variance in consumers perception error, i.e. the larger is σ_ω, a lower proportion of consumers would end up using between 90% and 110% of the allowance. Hence the proportion of consumers using between 90% and 110% of the allowance observed in the data identifies the parameter σ_ω, which determines the distribution of the perception error ω.

5.1.3 Identification of the distribution of the preference parameter θ_i

Recall that the preference parameter θ_i measures how many minutes consumer i will call monthly if the marginal price of calling is zero. I allow θ_i to vary as a function of a consumer's observable and unobservable characteristics. I restrict θ_i to be positive by specifying it as an exponential function of the consumer i's characteristics

$$\theta_i = exp(\bar{\theta} + \theta_D D_i + \nu_i) \tag{12}$$

where $\{\bar{\theta}, \theta_D\}$ are parameters and D_i is a column-vector of key demographic characteristics for consumer i (family dummy, the age of the head of the household is over 55 dummy, and renting dummy). ν_i represents a consumer's unobservable heterogeneity. I assume that ν_i follows a normal distribution with mean 0 and variance σ^2.

The aggregate level data (that is market shares of plans), would be enough to identify the variance of preference parameter θ_i. As discussed in Berry et al. (1995), a large variance of θ_i implies that the utility associated with plans with similar level of allowances will be highly positively correlated.

Additional micro level data allows more precise estimation of the parameters that determine the distribution of θ_i: the coefficients on three key demographic variables are identified using moment (2), the mean of monthly calling minutes for the eight combinations of three demographic groups (family, age, and rent); the coefficient that determines the unobservable heterogeneity σ is more precisely identified using moment (3), the coefficient of variation in monthly calling minutes.

5.1.4 Identification 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 price of the plan. These two price coefficients are identified separately using two different sets of moments.

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}. My instruments for the monthly fixed fee of plans follow standard practice in demand estimation on aggregate data. First, I allow observed product characteristics, Z_{jm}, to instrument for themselves.[26] Second, I account for price endogeneity by instrumenting for it with the average price of plans with similar allowance level offered in

[26] Observed product characteristics include dummy variables for non-minutes plan characteristics such as firm, year.

the same economic area groupings, but outside the same economic area.[27][28]

Table 9 shows economic areas in the estimation sample and the corresponding economic area groupings. The variation in prices across different allowance levels and across different economic area groupings identify the price coefficient. The first identification assumption is that the unobservable demand shock is uncorrelated, and the marginal costs are correlated within the same group defined by the allowance level. This assumption is justified since: (a)the utility from using the allowance has been taken out of the mean utility by construction; and (b) the size of the allowance affects the cost of the plan. The second identification assumption is that for plan j in economic area m, the unobservable demand shock is uncorrelated, and the marginal costs are correlated within the economic area grouping outside the economic area m. The latter is likely to be true as labor costs are often correlated within the economic area grouping. Dummies indicating the group to which the allowance level of the plan belongs are also included as instrumental variables. Since the utility from using the allowance has been taken out of the mean utility by construction, these instrumental variables are not correlated with unobservable demand shock; they are correlated with the plan's price because they affect the cost of the plan.

The price coefficient corresponding to the overage price, a_i, is identified using moment (4), the correlation of the monthly calling minutes with the overage price of the plan chosen by the two income levels. The variation in overage prices comes from the fact that big plans are usually associated with lower overage prices than small plans; with the presence of perception error, consumers' perceived marginal price is flatter for big plans than for small plans for two reasons: (a) consumers have smaller probability of paying overage prices for big plans than for small plans at any given perceived usage level; and (b) in case they pay overage prices they pay lower per minute price for big plans than for small plans.[29] Consumers with the same preference (same θ_i in equation (1)) end up choosing different size of plans because of a different realization of their logit error (ϵ_{ij} in equation (6)), which is assumed to be uncorrelated with plans' overage prices. For consumers with different preferences, I construct moment (4) conditional on the plan choice, hence the private information that consumers have at the plan choice stage is already accounted for.[30]

[27] I discretize the allowance level to six different groups: smaller than 100 minutes, between 100 to 200 minutes, between 200 to 300 minutes, between 300 to 400 minutes, between 400 to 600 minutes, and larger than 600 minutes.

[28] 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.

[29] Please see figure 3 for a demonstration.

[30] I accounted for the fact that consumers who know that they have a larger θ_i are more likely to choose plans with larger allowance level and lower overage price; the idea is similar to the standard Heckman correction.

5.2 The estimation of costs

As mentioned in the discussion of the 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. I 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.

In the counterfactual analysis, I allow the mobile network operators to re-optimize their pricing strategy in response to the regulation. To make the problem tractable, I 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 prices 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 prices provide two optimization conditions to identify the cost per customer and the cost per minute. These two optimization conditions for each mobile network operator f in market m can be expressed as

$$\begin{cases} \frac{\partial \pi_{fm}(LF_{fm}, Lp_{fm})}{\partial LF_{fm}} = 0 \\ \frac{\partial \pi_{fm}(LF_{fm}, Lp_{fm})}{\partial Lp_{fm}} = 0 \end{cases} \tag{13}$$

where $\pi_{fm}(LF_{fm}, Lp_{fm})$ is defined as

$$\begin{aligned} \pi_{fm}(LF_{fm}, Lp_{fm}) = & \sum_{j \in J_{fm}} s_{jm}(F_m(LF_{fm}), A_m, p_m(Lp_{fm}), J_{fm})(F_j(LF_{fm}) - C_{fm} \\ & + \int_i \{ \int_\omega p_j(Lp_{fm}) \max\{x_i^* \omega - A_j, 0\} - c_{fm}(x_i^* \omega)\, dF(\omega)\} dP_{ijm}(s_{ijm}, s_{jm})) \end{aligned} \tag{14}$$

In the counterfactual analysis, to implement the re-optimization of each mobile network operator's pricing strategy, I further restrict the domain of LF_{fm} and Lp_{fm} to be a discrete set $L = \{0.2, 0.4, \ldots, 1.8, 2\}$ for each f in each m. The profit maximization problem of mobile network f in market m implies that

$$\pi_{fm}(LF_{fm} = 1, Lp_{fm} = 1) \geq \pi_{fm}(LF'_{fm}, Lp'_{fm}) \text{for any } LF'_{fm} \in L \text{ and } Lp'_{fm} \in L. \tag{15}$$

Equation (15) partially identifies the feasible set of costs per consumer and costs per minute for each mobile network operator f in each market m. In addition, the two first order conditions for each firm-market pair point identify these two components of costs among the feasible set of costs.

6 Estimation Results

Table 10 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).

6.1 The perception error estimates

The perception error is identified using the smoothness of the distribution of usage ratio around 1 and the parametric assumption on the perception error.

Recall that 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, as explained in the model section, $\mu = -\frac{\sigma_\omega^2}{2}$. 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 usage ratio being between 0.90 and 1.10, that is, the probability that consumers' actual usage level is between 90% and 110% of the monthly allowance. Table 8 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.[31] Table 8 also shows the value of the key moment for another two values of the variance of ω, specifically, 25% and 50% of the estimated value. Table 8 confirms the discussion in the identification section: when σ_ω is zero, i.e. consumers have precise perception of their actual usage level, a large proportion of consumers end up using between 90% and 110% of the 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 proportion of consumers end up using between 90% and 110% of the allowance. See figure 4 for a demonstration.

6.2 The price coefficient estimates

As discussed in the previous section, the price coefficient for fixed fees and the price coefficient for overage prices are separately identified. The former is identified using the covariance of demand-side instruments,

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

Z^d_{jm}, with the unobserved demand shock ξ_{jm}; while the latter is identified using the correlation of the monthly calling minutes with the overage price of the plan chosen. The two price coefficients correspond to two different stages of consumer's decision process: the price coefficient for fixed fees correspond to the subscription decision, and the price coefficient for overage prices correspond to the calling decision.

Once adjusted by the logit standard error in the model, the difference between the two price coefficients is not statistically significant. The price coefficient for fixed fees is precisely identified through the use of instrumental variables for fixed fees; the estimation of the price coefficient for overage prices is implemented conditional on the plan choice, hence the private information that consumers have at the plan choice stage is already accounted for. The price coefficient for overage prices is not precisely identified partially due to the fact that the variation in overage prices across different plans is small (smaller than the variation in fixed fees across different plans in terms of coefficient of variation).

The 2nd and 3rd row of table 11 present the mean and standard deviation the price elasticities in terms of market shares of major mobile network operators with respect to the fixed fee levels. The subscription price elasticity is estimated to be -0.61, a value that is comparable with previous studies: Hausman (1999) reports a price elasticity of subscription of -0.51 for cellular subscription in the 30 largest U.S. markets over the period 1988-93.[32]

The own price elasticity of a particular firm 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 is increased by 1%, 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 1% 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 7%.

The 4th and 5th row of table 11 present the mean and standard deviation of the price elasticities in terms of overage minutes (which is the number of minutes that are charged with overage prices) of major mobile network operators with respect to the overage price levels. The overage minutes price elasticity of a particular firm in each market is computed as the percentage change of the number of overage minutes of this firm when the overage prices of all plans offered by this firm in this market is increased by 1% 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 price of all plans in one market by 1% while holding prices of other

[32]The subscription price elasticity is defined as the percentage change of penetration rate (the percentage of population with mobile phones) in one market with one percentage increase in fixed fees of all plans in the market.

firms in the same market constant, the number of overage minutes of Sprint would on average (average across markets where this firm is present) decreases by 2.52%.

6.3 The cost estimates

6.3.1 The cost per consumer estimates

The 6th and 7th rows of table 11 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 8th row of table 11 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 11 is the average of the 8 quarters in 2000-2001 reported in Global Wireless Matrix 2Q04 for major mobile network operators in US. The reason why the estimated cost per consumer is much lower than Merrill Lynch measure is that Merrill Lynch measure of monthly operating cost per consumer is computed using the average revenue per consumer reported by firms and the accounting margin reported by firms; and firms usually include the fixed monthly operating costs as defined in equation 11 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 of the number of consumers, hence should not be counted in the cost per consumer from an economics point of view.

6.3.2 The cost per minute estimates

The 9th and 10th row of 11 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.

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 capacity constraint is presented in the form of dropped calls in reality.

During the sample period, unlimited plans were uncommon; most plans were associated with high overage prices. This pricing structure was partially due to the high capacity constraint 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 the overage prices; hence the cost per minute estimates reflect the level of capacity constraint that made the overage prices 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 were offered in the last few years. The last row of table 11 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.[33]

7 The Welfare 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. I model consumers' perception error in recalling past usage as the source of such price uncertainty. In other words, consistently with this modeling strategy, I now simulate the welfare effects of the "Bill Shock" regulation by running a counterfactual whereby the consumers' perception error is eliminated.

I first show what would happen to welfare 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 my counterfactual, I allow mobile network operators to adjust their pricing structures, and show what would happen to welfare in the new price equilibrium.[34]

[33] Please refer to table 2 in Littlechild (2006).

[34] As mentioned in the data section: Among plans offered by the five major operators, 95% of matched bills have fixed fees in the \$19.99-\$59.99 range. For each major operator in each market, I aggregate plans with fixed fees higher than \$59.99 into one plan. The monthly fixed fee, allowance and overage price of the aggregated plans is the average of plans included in the aggregation.In the counterfactual analysis, I keep the expensive plans unchanged. Consumers would still have uncertainty about their usage under these plans and the pricing structure of these expensive plans are unchanged in the new price equilibrium. I made this compromise for the following reasons: Even though expensive plans were offered by all major mobile network operators, the expensive plans were observable for some mobile network operators and not observable for other mobile network operators in the estimation sample within a given market because it is hard to draw households with expensive plans; if the expensive plans were kept when I allow mobile network operators readjust their prices in the counterfactual scenario, the expensive plans would drive the mobile network operator with expensive plans observed in the estimation sample to adjust the price in a weird direction (decrease fixed fees and increase overage prices) and the expensive plan would have the dominant

7.1 Counterfactual analysis where perception error is eliminated for all consumers

In this counterfactual analysis, the perception error is eliminated for all consumers. The consumer's calling decision described in equation 1 becomes

$$\max_{x_{ij}} v_{ij}(x_{ij}) = \theta_i ln x_{ij} - a_i p_j \mathbf{1}_{x_{ij}>A_j}(x_{ij} - A_j) + x_{i0} \tag{16}$$

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

The optimal usage x^*_{ij} equates the marginal utility to the opportunity cost for the next calling minute:

$$\underbrace{\frac{\theta_i}{x_{ij}}}_{\text{MU for the next calling minute}} = \underbrace{a_i p_j \mathbf{1}_{x_{ij}>A_j} + 1}_{\text{opportunity cost of the next calling minute}} \tag{17}$$

and thus

$$x^*_{ij}(\theta_i, A_j, p_j) = \begin{cases} \theta_i & \text{if } \theta_i < A_j, \\ A_j & \text{if } \theta_i \in [A_j, A_j(1 + a_i p_j)], \\ \frac{\theta_i}{1+a_i p_j} & \text{if } \theta_i > A_j(1 + a_i p_j). \end{cases} \tag{18}$$

Consumers' subscription decision and mobile network operators' pricing decisions will also change according to the model of subscriptions and pricing.

7.1.1 The welfare effects with the unchanged pricing structure

Table 12 presents the monthly per household and total effect of the "Bill Shock" regulation keeping the pricing structure unchanged.[35] From table 12, we can see that the monthly industry profit would be decreased by \$642 million if mobile network operators kept prices unchanged after the elimination of the perception error

market share. In the end, I made the choice of keeping expensive plans similar to an outside option: they would stay exactly the same in the counterfactual scenario.

[35] I first computed 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 (which is computed by dividing the number of population reported in Census in the year 2000 with the mean number of people in one household in each market computed from the national survey data described in the data section). The numbers reported in table 12 are the sums of the total effects of the 26 markets in the estimation sample. The per household effect reported in table 12 is computed by dividing the total effect reported in table 12 with the total number of households in 26 markets in the estimation sample. The monetary values reported in table 12 are in year 2000 dollars.

for all consumers.

More than half of this loss would come from the \$335 million decrease in monthly overage payment. After consumers receive information on their usage level and no longer have uncertainty regarding marginal price, 63% of subscribing consumers would call exactly their allowance. The probability of overage decreases from 0.21 to 0.05.

An additional reason why industry profit decreases is that consumers switch plans. If consumers are uncertain about price, they may choose a large-allowance plan as a mean to insure against unexpected overage payments. If price uncertainty is eliminated, such consumers switch to a lower-allowance plan, which charges a lower fixed fee. Specifically, in Table 12, I distinguish between large plan and small plan: for a given consumer, a large plan is defined as one with an allowance that is greater than consumer demand at zero price.

7.1.2 The welfare effects with the price response

To compute the new price equilibrium when the perception error is eliminated for all consumers under the "Bill Shock" regulation, I define the pricing strategy of each mobile network operator f in each market m to be: readjusting the level of fixed fees LF_{fm} of all plans and the level of overage prices 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 firm pricing strategy in the absence of consumer perception error.[36]

Table 13 shows the changes in fixed fees and overage prices in the new price equilibrium: all major mobile network operators increase their fixed fees, with increases ranging from 39% to 45%; and decrease their overage prices, with decreases ranging from 57% to 63%.

Table 14 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 14. There are two reasons for this difference. One is that the decrease in overage prices leads to more consumers incurring overage payments, from 5% to 42%. The second reason is that lower overage prices increase consumer valuations for the plan, which in turn allows network operators to increase fixed fees.

In terms of welfare, the elimination of the consumer's 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

[36] To implement the re-optimization of each mobile network operator's pricing strategy, I further restrict the domain of LF_{fm} and Lp_{fm} to be a discrete set $L = \{0.2, 0.4, \ldots, 1.8, 2\}$ for each f in each m. Given the pricing strategy of other firms in the market, firm f's best response is found by a grid search of maximum profit among profits at all the possible combination of values of LF_{fm} and Lp_{fm}.

cost per consumer; this price increase leads to a decrease in penetration rate from 55% to 48% and to a loss in welfare. On the intensive margin, the decrease in overage prices shrinks the gap between the overage prices 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 intensive margin surpasses the welfare loss from extensive margin, resulting in a positive net welfare effect. The welfare gain is captured by consumers (2% increase in consumer surplus), while the industry profit does not change.[37]

The "Bill Shock" regulation also imposes an important distributional effect on consumer surplus: the increase in fixed fees and decrease in overage prices has different implications for different types of consumers. Table 15 displays the consumer welfare effects where consumers are classified according to their preference parameter (the lower quartiles corresponding to lighter users). For consumers in the second and third quartiles of the preference distribution, the loss due to higher fixed fees surpasses the gain due to lower overage prices. By contrast, for consumers in the fourth quartile, the increase in fixed fees has almost no impact on the penetration rate, and the gain due to lower overage prices dominates.

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

7.2 Counterfactual analysis robust check

In essence the "Bill Shock" regulation consists of informing consumers when their allowance limit has been reached. In my base counterfactual, I simulate this by eliminating the perception error. However, if consumption is lower than the monthly allowance no usage information is provided to consumers; that is, the perception error is not completely eliminated as a result of the "Bill Shock" regulation.

In this section, I perform an alternative counterfactual that reflects this difference: consumers whose consumption exceeds the monthly allowance receive information regarding their actual usage level; by contrast, consumers whose consumption falls short of the monthly allowance do not receive information other than the fact that their usage is lower than the monthly allowance.

More formally, I now assume that the consumer's calling decision is described by

$$\max_{x_{ij}} v_{ij}(x_{ij}) = \begin{cases} \int_{\omega_c \in (0, \frac{A_j}{x_{ij}}]} \theta_i ln(x_{ij}\omega_c) + x_{i0} dF(\omega_c) & \text{if } \theta_i < A_j, \\ \theta_i ln x_{ij} - a_i p_j \mathbf{1}_{x_{ij} > A_j}(x_{ij} - A_j) + x_{i0} & \text{if } \theta_i \geq A_j, \end{cases} \tag{19}$$

$$\text{subject to} \quad \int_{\omega_c \in (0, \frac{A_j}{x_{ij}}]} (x_{ij}\omega_c) dF(\omega_c) \mathbf{1}_{\theta_i < A_j} + x_{ij}\mathbf{1}_{\theta_i \geq A_j} + \underbrace{x_{i0}}_{\text{outside activity}} \leq \underbrace{T}_{\text{time constraint}}$$

The optimal usage level x^*_{ij} equates the marginal utility to the opportunity cost for the next calling minute.

$$\underbrace{\frac{\theta_i}{x_{ij}}}_{\text{MU for the next calling minute}} = \underbrace{a_i p_j \mathbf{1}_{x_{ij} > A_j} + 1}_{\text{opportunity cost of the next calling minute}} \tag{20}$$

and thus

$$x^*_{ij}(\theta_i, A_j, p_j) = \begin{cases} \theta_i & \text{if } \theta_i < A_j, \\ A_j & \text{if } \theta_i \in [A_j, A_j(1 + a_i p_j)], \\ \frac{\theta_i}{1 + a_i p_j} & \text{if } \theta_i > A_j(1 + a_i p_j). \end{cases} \tag{21}$$

The realized usage for consumers whose preference is to call less than the monthly allowance (i.e. $\theta_i < A_j$) is the product of the optimal perceived usage and the perception error: $x_{ij} = x^*_{ij}\omega_c \in (0, A_j]$; the realized usage for consumers whose preference is to call more than the monthly allowance (i.e. $\theta_i \geq A_j$) is the optimal usage they would like to call: $x_{ij} = x^*_{ij}$. The maximum monthly utility from calling using plan j for consumer i is hence

$$v_{ij}(x^*_{ij};\theta_i,a_i,A_j,p_j)=\begin{cases}\int_{\omega_c\in(0,\frac{A_j}{x^*_{ij}}]}\theta_i ln(x^*_{ij}\omega_c)+T-(x^*_{ij}\omega_c)dF(\omega_c) & \text{if } \theta_i<A_j,\\ \theta_i ln x^*_{ij}-a_ip_j(x^*_{ij}-A_j)+T-x^*_{ij} & \text{if } \theta_i\geq A_j,\end{cases} \tag{22}$$

Consumers' subscription decisions and mobile network operators' pricing decisions will also change using the model of subscriptions and pricing.

The welfare effect of the "Bill Shock" regulation with adjusted prices in this alternative counterfactual is presented in table 16. The result is very similar to the counterfactual scenario where the perception error is completely eliminated.

8 Conclusion

I study the welfare 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 data set, I estimate an industry model of calling, subscription and pricing. My counterfactual simulations predict that the proposed regulation has two conflicting welfare effects: a positive effect from lower overage prices and a negative effect from higher fixed fees. In net terms, I predict a 2% increase in consumer surplus, while industry profit remains constant. Moreover, the regulation benefits heavy users and hurts light users.

This paper is one of the first to contribute to understanding the welfare effects of consumer protection policies that attempt to reduce consumer price uncertainty. The prediction of the direction of changes in price and welfare could be indicative of policies aimed at other important industries with similar issues: home mortgages, health insurance, and debit and credit cards. This paper suggests that firms will adjust prices in response to this type of consumer protection policy, and that the price adjustment could impose an important distributional effect on different types of consumers.

Because of the limitation in the data, I need to impose parametric assumptions on the distribution of the perception error. One possible direction to relax this assumption is to conduct a field study on people's perception error: for example, contact consumers at the end of the monthly billing cycle, just before they see their monthly bill, and ask about their perceived usage for that month; the difference between their perceived usage and their actual usage in the bill is the perception error; a large enough sample of perception errors could show the real shape of the distribution of the perception error.

Another limitation in the data used in this paper is that each consumer is observed only once. In future work, a panel data set that tracks the same individual would allow more flexible specification of the model: consumers only have information on the distribution of their preferences at the plan choice stage and observe the realization of their preferences for a particular month at the beginning of each month. Lambrecht et al. (2007) shows that monthly usage variation makes three-part tariffs more profitable than two-part tariffs. Future work could try to separately quantify the implication of monthly usage variation that is controlled by consumers (as in Lambrecht et al. (2007)) and the perception error that consumers cannot control (as in this paper) on the pricing design of three-part tariffs.

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A Tables and Figures

Table 1: Mean comparison among different consumer samples in TNS data in 2000-2001

	the whole sample	the sample with mobile phones	bill data
number of HH	262,826	130,259	16,087
family	0.73	0.83	0.79
head age over 55	0.38	0.28	0.38
renting	0.30	0.24	0.18
high income	0.63	0.75	0.79

Table 2: 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 3: Summary statistics of bill data and call detail data

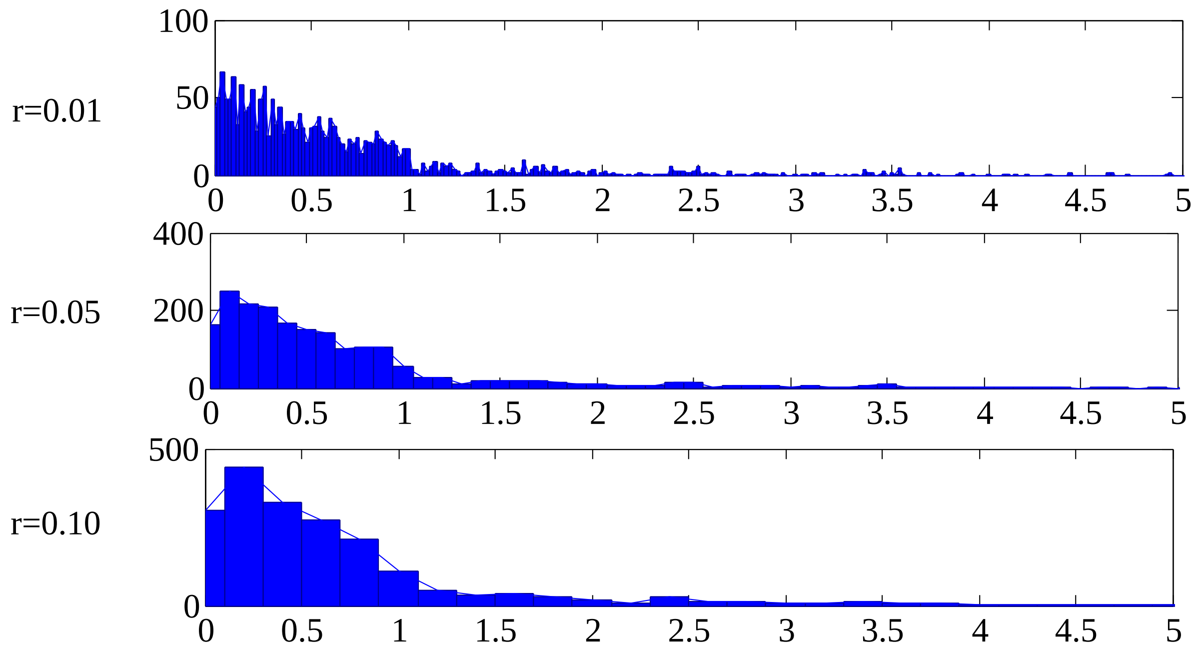
Bill data					
variable	number of bills	mean	std. dev.	min	max
fixed fee $/mo	16,894	32.20	22.80	0.00	349.98
free min used/mo	16,986	115.84	269.91	0.00	5473
billed min/mo	16,986	36.67	148.03	0.00	3256
total min used/mo	16,986	154.29	329.03	0	5715
Call detail data: billed calls					
bills with billed 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 that are not charged (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 4: Plans offered by AT&T in New York at 1/5/2001

fixed fee $/mo	allowance min/mo	overage price $/min	coverage	ld price $/min	roam price $/min
19.99	60	0.4	Local	0.15	0.6
29.99	120	0.3	Regional	0	0.6
29.99	250	0.6	Local	0.15	0.6
39.99	200	0.3	Regional	0	0.6
39.99	400	0.55	Local	0.15	0.6
49.99	400	0.3	Regional	0	0.6
49.99	600	0.45	Local	0.15	0.6
59.99	450	0.35	National	0	0
69.99	600	0.25	Regional	0	0.6
69.99	800	0.4	Local	0.15	0.6
79.99	650	0.35	National	0	0
99.99	900	0.25	National	0	0
99.99	1000	0.25	Regional	0	0.6
99.99	1200	0.4	Local	0.15	0.6
119.99	1100	0.25	National	0	0
149.99	1500	0.25	National	0	0
149.99	1600	0.25	Regional	0	0.6
149.99	2000	0.2	Local	0.15	0.6
199.99	2000	0.25	National	0	0
199.99	3000	0.2	Local	0.15	0.6

Figure 1: Histogram of the usage ratio in the data



For 1,987 observations in the estimation sample, 1,960 of them have usage ratio between 0 and 5. The histogram represents the number of observation within an interval. The length of the interval is set to be 0.02, 0.10 and 0.20 respectively. r is the radius of interval: the distance between the boundary of the interval and the center of the interval. For example, for r=0.10, the histogram around 1 represents the number of observations with usage ratio between 1-0.10 and 1+0.10 in the estimation sample.

Table 5: Successful rate of data matching by mobile operators

	bill count	matched bill count	% of success
Sprint	698	307	43.98%
AT&T	1,117	913	81.74%
VoiceStream Wireless(T-mobile)	285	264	92.63%
Verizon	1,596	884	55.39%
Cingular	557	286	51.35%
Others	1,942	338	17.40%
Total	6,195	2,992	48.30%

Table 6: Summary statistics in the estimation sample

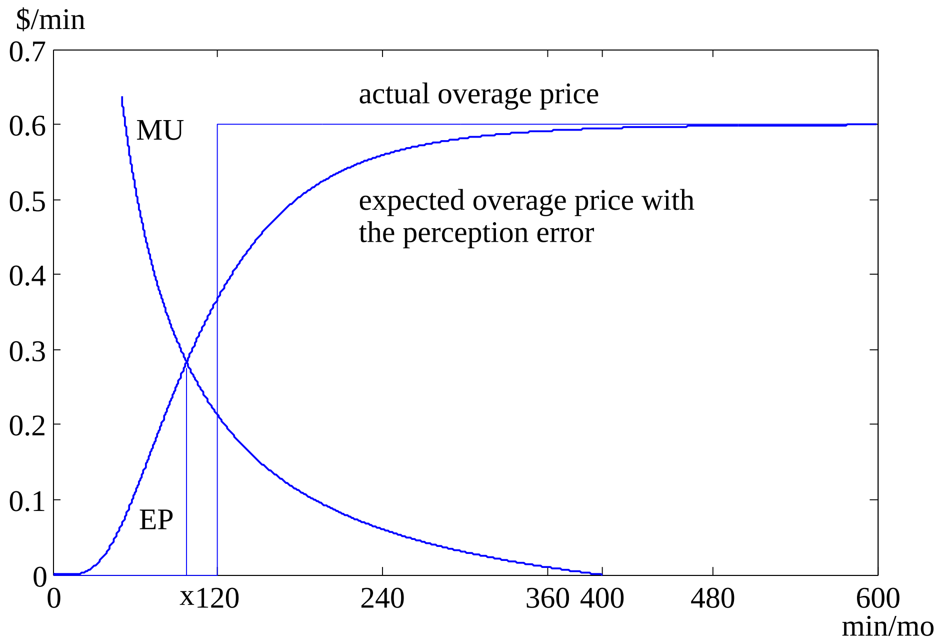
Aggregate data					
Variable	number of plan	mean	std. dev.	min	max
fixed fee ($/mo)	577	40	17	15	128
allowance (min/mo)	577	311	238	0	1400
overage price ($/min)	577	0.35	0.07	0.18	0.65
free long distance calls	577	0.48	0.50	0.00	1.00
free roaming calls	577	0.27	0.44	0.00	1.00
market share	577	3%	2%	0%	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

This table shows the summary characteristics of key variables of aggregate level and micro level data in the estimation sample. At the aggregate level, there are in total 577 plans in all 26 markets considered. At the micro level, there are in total 1,987 cell phone bills in all 26 markets considered. The 1,987 bills are used to approximate the market shares of 577 plans.

Table 7: Number of bills with most popular plans

number of free minutes	number of bills in the data	number of bills in the tail	percentage in the tail
20 minutes	74	21	28%
30 minutes	63	14	22%
60 minutes	157	30	19%
100 minutes	50	9	18%
120 minutes	185	30	16%
150 minutes	88	22	25%
200 minutes	225	39	17%
250 minutes	261	38	15%
300 minutes	78	4	5%
350 minutes	59	5	8%
400 minutes	125	25	20%
450 minutes	54	5	9%
500 minutes	52	7	13%
600 minutes	70	8	11%
other	446	83	19%
total	1,987	340	17%

Figure 2: Demonstration of the impact of perception error on consumer's calling decision and overage payment

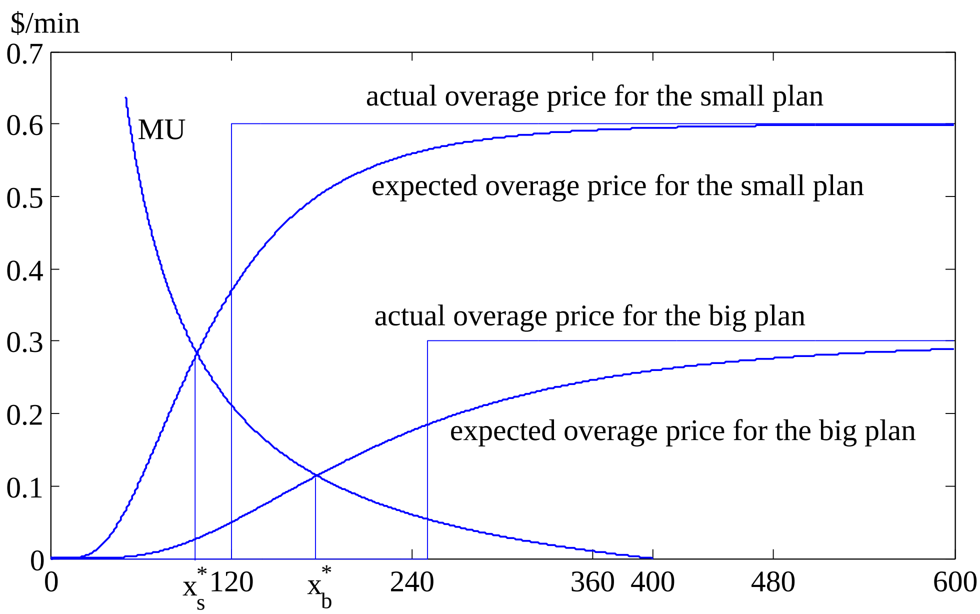


In this graph, the real marginal price per minute is 0 when the monthly calling minutes is less than 120 minutes and then jumps to \$0.60/min. If consumer is perfectly certain about the usage, this consumer would stop calling at exactly 120 minutes in this example. With the perception error, the perceived 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 price applies; taking this fact into account, the perceived marginal price per minute is positive at any perceived usage. This consumer would stop calling at point x. In expectation, the expected overage payment is represented by the area EP.

Table 8: Comparison of the moments from model simulations and from data

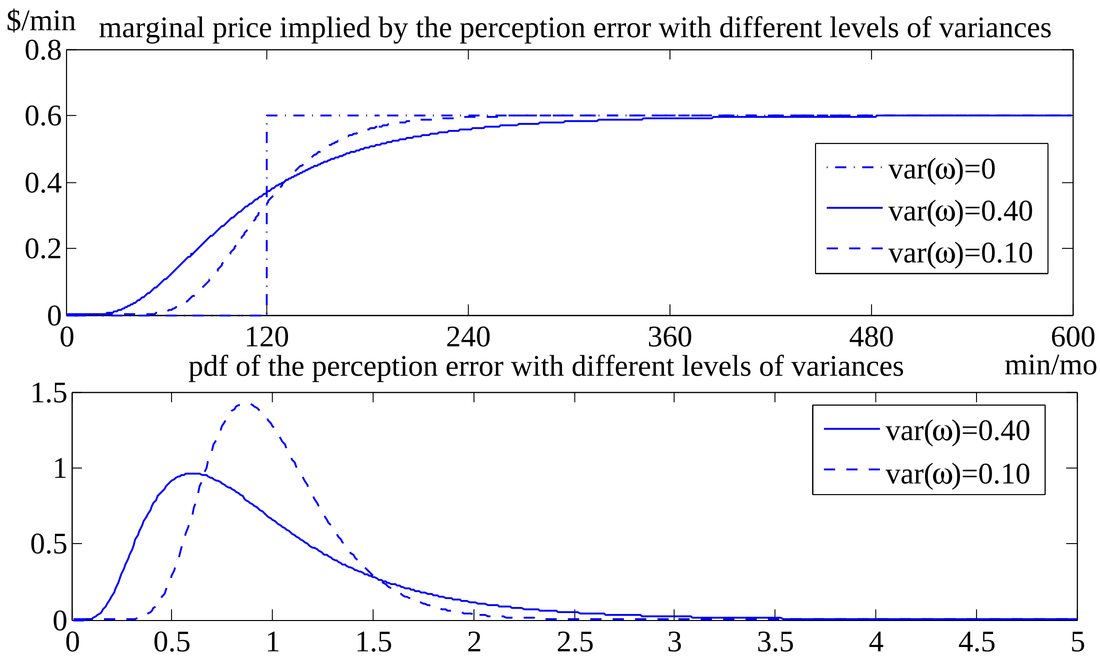
	prob of usage ratio is between 0.90 to 1.10
data	0.06
model simulation: variance of omega=0.40 ($\sigma_\omega = 0.58$)	0.07
model simulation: variance of omega=0 ($\sigma_\omega = 0$)	0.70
model simulation: variance of omega=0.10 ($\sigma_\omega = 0.31$)	0.13
model simulation: variance of omega=0.20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

Figure 3: Demonstration of the variation in overage prices of plans with different levels of free minutes included



This graphs shows the actual and consumer perceived expected overage price per minute for two plans: a small plan with 120 free minutes and the overage price of $0.60/min, and a big plan with 250 minutes and the overage price of $0.30. The expected overage price at each perceived usage equals the probability that actual usage level is greater than the free minutes included multiply by the actual overage price. Since there is a higher probability that consumers' actual usage is greater than 120 minutes than 250 minutes, and the small plan with 120 free minutes has a higher actual overage price ($0.60) than the big plan with 250 free minutes ($0.35/min), consumer perceived expected overage price per minute is higher at any perceived usage level for the small plan than for the big plan; as a consequence, for consumers with the same marginal utility curve, those choosing small plan would on average call less than those choosing big plan.

Figure 4: Demonstration of the identification of the variance of the perception error



From this graph, we could see that when the perception error's variance is zero (consumers' perceived usage perfectly coincide with their actual usage, the marginal price suddenly jumps from 0 to $0.60/ minutes at 120 minutes; when the variance of perception error is 0.40 as estimated, consumers' perceived marginal price is smoothed out around 120 minutes since consumers have uncertainty towards their actual usage: when their perceived usage is 120 minutes, their actual usage may be lower or higher than 120 minutes depending on the realization of the perception error; when the variance of perception error is 25% as estimated (0.10), consumers perceived marginal price changes more drastically around 120 minutes than when the variance of perception error is 0.40, and the realization of perception error is also more concentrated around 1 as shown in the pdf of the perception error with different levels of variances (both effects would increase the probability of consumers' usage being around 120 minutes).

Table 9: Economic areas in the estimation sample and the corresponding Economic Area Groupings

Economic Areas	Economic Area Groupings
Boston	Northeast
New York	Northeast
Charlotte	Mid-Atlantic
Philadelphia	Mid-Atlantic
Pittsburgh	Mid-Atlantic
Washington-Baltimore	Mid-Atlantic
Atlanta	Southeast
Miami	Southeast
Orlando	Southeast
Chicago	Great Lakes
Detroit	Great Lakes
Minneapolis	Great Lakes
Dallas	Central/Mountain
Denver	Central/Mountain
Phoenix	Central/Mountain
Salt Lake City	Central/Mountain
Los Angeles	Pacific
Sacramento	Pacific
San Francisco	Pacific
Seattle	Pacific

Table 10: Estimates of parameters in the model

	parameter estimate	standard error	interpretation
income effect with respect to the fixed fee	0.09	0.44	
logit standard error	68.12	48.00	
mean preference parameter	4.93***	1.02	
standard deviation of unobservable heteogeneity	0.98***	0.30	
standard deviation of log of perception error	0.58**	0.27	
price coefficient with respect to the overage price	-10.98	15.62	
income effect with respect to the overage price	3.44	22.22	
preference shifter: family	0.08	0.13	
preference shifter: hh head age over 55 dummy	-0.05	0.14	
prefence shifter: renting dummy	0.10	0.21	
year dummy: year 2000	-2.11***	0.63	compared with year 2001
AT&T dummy	-0.37	0.28	compared with Verizon
Cingular dummy	-1.20***	0.41	compared with Verizon
Sprint dummy	-1.48***	0.47	compared with Verizon
VoiceStream (T-mobile) dummy	-3.21***	0.49	compared with Verizon
Other carrier dummy	-1.30*	0.70	compared with Verizon
free long distance dummy	-1.38***	0.20	
free roaming dummy	0.53**	0.27	
price coefficient with respect to the fixed fee	-0.29***	0.01	

Table 11: Estimates for price elasticities and costs

	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 price	-2.52	-2.26	-3.00	-2.40	-2.08
std.dev	0.78	1.08	1.42	1.12	0.33
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				

Number of markets is the number of markets where a particular firm is present.

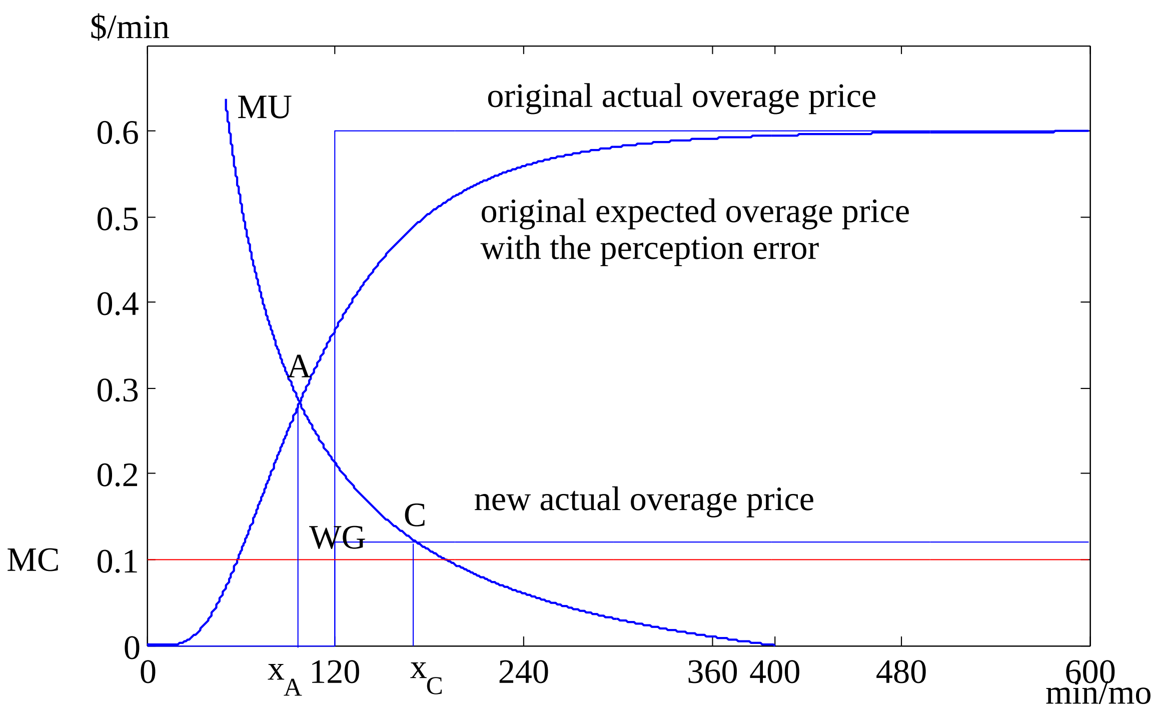
Table 12: The welfare effect of the "Bill Shock" regulation assuming no price adjustment

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	143	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	$97	$10	11%
mobile operators profit	$4	-$4	-$8	-200%
total surplus	$91	$93	$2	2%
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	12 million	3 million	-9 million	
monthly overage payment	$370 million	$35 million	-$335 million	
Welfare outcomes				
total consumers surplus	$6940 million	$7800 million	$860 million	
total mobile operators profit	$347 million	-$295 million	-$642 million	
total surplus	$7287 million	$7504 million	$217 million	

Table 13: Changes in fixed fees and overage prices 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 prices	-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 ($/mo)	19	20	16	16	21
mean of minimum overage prices before regulation ($/min)	0.36	0.28	0.23	0.30	0.35
mean of minimum overage prices 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

Figure 5: Welfare gain from the decrease in overage prices



The decrease in overage prices leads to the increase in calling (from point A to point C). Because the new actual overage price is closer to the marginal cost per minute than the original expected overage price with the perception error, the increase in calling generates a welfare gain (area WG in the graph).

Table 14: The welfare 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	134	19	17%
prob of using exactly free	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	8400 million	400 million	
number of hh making overage	12 million	22 million	10 million	
monthly overage payment	$370 million	$371 million	$1 million	
Welfare outcomes				
total consumers surplus	$6940 million	$7098 million	$158 million	
total mobile operators profit	$347 million	$352 million	$5 million	
total surplus	$7287 million	$7450 million	$163 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 for the cost per minute that is $0.13, the slight increase in the total industry profit is completely offset.

Table 15: 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%
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 different quartile of the preference distribution. For consumers whose preference parameters are in the second and third quartile 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 prices. 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 prices has dominant effect.

B The proposed "Bill Shock" regulation

The following text is coming 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.

C Data Matching and Construction of Estimation Sample

In this section, I discuss the process of matching the bill data with the tariff data. I define a market as an economic area-year pair. I match bills with the tariff data using market-operator-fixed fee listed in both sources. Table 5 shows the successful rate of data matching for five major mobile operators in 2000-2001.[38]

I use 2,992 matched bills to construct the market share of plans. Bills that belong to the five major operators account for 80% of matched bills in the sample.[39] Among plans offered by the five major operators, 95% of matched bills have fixed fees in the \$19.99-\$59.99 range. For each major operator in each market, I aggregate plans with fixed fees higher than \$59.99 into one plan.[40] [41]

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, I exclude these 80 markets from the estimation sample. Among the remaining 28 markets, I also exclude one market from year 2000 and one market from year 2001 where the majority of bills belong to non-major carriers and non-major plans. In the end 6 markets in 2000 and 20 markets in 2001 remain in the estimation sample.

[38]I distinguish plans with the same market-operator-fixed fee, but that differ in terms of whether offer free roaming calls or long distance calls. I 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. I also check if the usage level recorded in the bill is consistent with the allowance level of the plan. I drop the matches that are inconsistent. Please refer to the appendix for additional details on the data matching process.

[39]The five major operators are: Sprint, AT&T, Voicestream Wireless(T-mobile), Verizon, and Cingular. I aggregate all plans offered by operators other than the five major operators in each market.

[40]The monthly fixed fee, allowance and overage price of the aggregated plans is the average of plans included in the aggregation.

[41] Whether plans offer free long distance calls or free roaming calls are two key characteristics that define the coverage of the plan: Local plans offer neither for free; regional plans often offer the long distance call for free but charge for roaming calls; and national plans often offer both for free. For plans that are aggregated from operators other than the five major operators, I define neither long distance calls nor roaming calls to be free; for plans that are aggregated to be expensive plans by one of the five major operators, I define both long distance calls and roaming calls to be free since these expensive plans are often national plans.

D Bunching at the allowance level

In this section, I use a simple model to demonstrate why we should expect a mass point of consumers using exactly the allowance level if they are perfectly aware of the marginal price of next calling minute.

Consider a large number of consumers. Each one of them draw his/her preference parameter θ_i from a continuous distribution such as log-normal distribution. All consumers are using the same three-part tariff with monthly fixed fee F, allowance A and overage price p.

Consumer i is facing a time constraint T. He/she chooses to allocate the time to talk on the mobile phone or to spend on the outside activity (the marginal utility of which is normalized to 1) subject to the time constraint T. Under the assumption that consumers are perfectly aware of the marginal price, consumer i chooses the quantity of calling minutes x_i and the quantity of time spending on the outside activity x_{i0} to maximize his/her surplus

$$\max_{x_i} v_{ij}(x_i) = \theta_i ln x_i - ap\mathbf{1}_{x_i>A}(x_i - A) + x_{i0} \tag{23}$$
$$\text{subject to} \quad x_i + x_{i0} \leq T$$

where a is the income effect. The indicator function $\mathbf{1}_{x_i>A}$ implies that consumers are only charged the overage price p as the marginal price of the next calling minute if they use up their allowance level A.

The optimal usage level x_i is given by the usage level at which the marginal utility equals to the opportunity cost for the next calling minute.

$$\underbrace{\frac{\theta_i}{x_i}}_{\text{MU for the next calling minute}} = \underbrace{ap\mathbf{1}_{x_i>A} + 1}_{\text{opportunity cost of the next calling minute}} \tag{24}$$

Solving the equation 24, the optimal usage level x_i^* can be expressed as a function of preference parameter θ_i, allowance A and overage price p.

$$x_i^* = \begin{cases} \theta_i & \text{if } \theta_i < A, \\ A & \text{if } \theta_i \in [A, A(1+ap)], \\ \frac{\theta_i}{1+ap} & \text{if } \theta_i > A(1+ap). \end{cases} \tag{25}$$

Equation 25 shows that for consumers whose preference parameter θ_i falls in between of A and $A(1+ap)$, the optimal usage level x_i^* is exactly the allowance level A. Since θ_i has a continuous distribution, the probability that θ_i falls in between of A and $A(1+ap)$ is strictly greater than 0. Hence, a mass point of consumers should use exactly the allowance level.

E The expected overage payment and the expected marginal price of the next calling minute

As presented in equation 1, consumers' expected overage payment is

$$\int_\omega p_j \max\{x_i\omega - A_j, 0\}\, dF(\omega).$$

ω follows a distribution with the probability density function $f(\omega)$ and the cumulative distribution function $F(\omega)$. Taking derivative of the expected overage payment with respect to x_i, I can derive the expected marginal price of the next calling minute as following.

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

F 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.

G Additional details on the data

G.1 Additional details on TNS bill data

Among households with bills, 9,334 households appear only once, 3,216 households appear twice and 107 households appear three times during the 8 quarters in 2000-2001. 15,276 households handed in 1 bill, 744 households handed in 2 bills and 50 households handed in more than 2 bills when they are in the quarterly sample.

Matching the bill data with the national survey data, I can see how many mobile phones households with bills own. Among 16,557 matched bills, 10,242 bills indicate 1 mobile phone is owned by the household, 5,117 bills indicate 2 mobile phones and 1,198 indicate more than 2 mobile phones. Table 17 shows the number of mobile phones owned by households interacting with the size of the household. 522 bills appear on the upper right diagonal indicating ownership of multiple mobile phones by one person in the household.

In the bill, there is information on how many lines is on this bill. Among 16,914 bills with information on number of lines on the bill, 13,304 bills indicate a single line on the bill and 3,610 bills indicate multiple lines on the bill. More than one lines appearing on the bill is the indication of using family plans (multiple members sharing the same plan to get the price discount). Table 18 shows the number of lines on the bill interacting with the number of mobile phones owned by the household. 333 bills appear on the lower left diagonal indicating more lines on the bill than the number of mobile phones the household owns. The explanation is that people sometimes share a family plan with relatives or friends outside of the households.

G.2 Additional details on Data Matching

Among original 17,155 bills that have bill level information, 241 bills lack demographic information, 754 bills miss information of the monthly fixed fee of the plan chosen or the location (economic area) of the bill, 404 bills have monthly fixed fee lower than $9.9 or have the year of billing not in 2000-2001. After dropping these bills, 15,756 bills left. Among these 15,756 bills, 222 bills are business bills. Dropping these business bills, 15,534 bills left. Among these 15,534 bills with bill level information, 10,001 bills have call detail level information. These 10,001 bills are used to match with the tariff data.

Among 10,001 bills used to match with the tariff data, 6,982 bills have the fixed fee level appeared in the tariff data. The fixed fee on other 3,019 bills may be recorded with error or belong to plans offered prior to 2000. Verizon started operating in may, 2000. I also drop 787 bills that were dated prior to the establishment of Verizon (I am focusing on the major operators in 2000-2001. Among these major operators, Verizon started operating in 05/2000 and Cingular started operating in 01/2001. These two dates are used as the starting point of each year in the market definition). In the end, 6,195 bills left to match with the tariff data.

Table 16: The welfare effect of the "Bill Shock" regulation with adjusted prices in the robust check

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	131	16	14%
prob of using exactly free minutes in the plan (cond on subscription)	0.00	0.37	0.37	-
prob of making overage payment (cond on subscription)	0.21	0.45	0.24	114%
mean monthly overage payment(cond on pay overage)	$24	$11	-$13	-54%
Welfare outcomes				
mean consumers surplus	$87	$89	$2	2%
mobile operators profit	$4	$4	$0	0%
total surplus	$91	$93	$2	2%

Table 17: Number of mobile phones owned by households in the bill data

	number of mobile phones		
size of hh	1	2	3 or more
1	2,986	293	45
2	3,922	1,952	184
3	1,489	1,169	278
4	1,166	1,097	394
5	679	606	297
Total	10,242	5,117	1,198

Table 18: Number of lines in the bill

	number of mobile phones		
number of lines	1	2	3 or more
1	9,507	2,859	634
2	190	1,926	252
3	19	49	205
4	2	6	40
5	0	2	5
Total	9,718	4,842	1,136