Product Bundles under Three-Part Tariffs [1]

Ping Xiao

Tat Chan

Chakravarthi Narasimhan[2]

November, 2006

[1] This is a very preliminary draft. Please do not cite without permission from the authors.

[2] Ping Xiao is a doctoral student in Marketing, Tat Chan is an Assistant Professor of Marketing, and Chakravarthi Narasimhan is the Philip L. Siteman Professor of Marketing, all at Washington University in St. Louis. Chan and Narasimhan would like to acknowledge the funding support from BCTIM.

Product Bundles under Three-Part Tariffs

Abstract

Product bundling and non-linear pricing are popular marketing strategies in industries such as wireless and internet. While each has been extensively studied separately in the economics and marketing literature there are no theoretical or empirical studies that consider both simultaneously. When consumers are exposed to different product bundles that in turn contain several two or three part tariffs it is important to understand the drivers of consumer choices. The consumer references for multiple products within bundles may be correlated; understanding such a preference structure could potentially lead firms to choose the optimal tariffs to offer and decide whether they should bundle different services or offer each service plan at a separate price. Further, consumers face both out of pocket and psychological costs for switching between plans or dropping out of the market. Consumers may not be able to evaluate their level of consumption for the services offered and will only learn this over time. These behaviors are potential factors which determine how consumers choose or switch among product bundles. To explore these issues we develop a structural model to study consumers' product bundle choice and usage decisions, and estimate the model using a dataset from a wireless service provider. We find switching costs and consumer learning play an important role in explaining the switching patterns observed in the data. Based on the estimation results, we conduct policy experiments to examine the focal firm's optimal pricing decisions. Results show that both while bundling increases firms profit through extracting consumer surplus, three-part tariff strategies help to increase firms profit but may also increase consumer surplus hence create a win-win situation. Furthermore, when consumer preferences for multiple products and services are positively correlated, the optimal pricing scheme is a combination of two-part and three-part tariff service plans. A counter-factual pricing experiment

shows that, when consumer preferences are negatively correlated, the optimal pricing scheme will be a combination of two three-part tariff service plans.

1. Introduction

Three-part tariff is a non-linear pricing mechanism popular in industries such as wireless, internet and rental markets. The pricing structure under a three-part tariff scheme includes a fixed access fee, an amount of free usage (allowance), and a marginal price per unit for any additional usage above the free amount. Jensen (2006) finds that implementation of a simple two-part tariffs may not be an equilibrium strategy in a duopoly and analytically demonstrates a three-part tariff as an equilibrium nonlinear pricing strategy in a differentiated product duopoly case. Grubb (2005) shows that three-part tariff is optimal in markets where marginal costs are low and consumers are over-confident in their prediction of future usage. A few other empirical studies also examine consumer's choice and usage decisions under three-part tariffs (see Iyengar 2005 and Lambrecht, Seim and Skiera 2005). All of the above studies only consider a single product. However, bundling is also a popular marketing practice in many industries, some examples include hamburgers sold with french fries and a soft drink, checking, credit cards and investment services bundled together, hardware bundled with software and peripherals in the computer industry.

Prior research has addressed the use of bundling as a mechanism for second-degree price discrimination by a monopolist to extract consumer surplus (Adams and Yellen (1976), Schmalensee (1984), McAfee, McMillan, and Whinston (1989), Salinger (1995), Armstrong (1999), Bakos and Brynjolfsson (1999), Crawford (2005), Chu, Leslie and Sorensen (2006) etc.). Adams and Yellen (1976) show that bundling can increase a monopolist's profit when consumer preferences for the two products are negatively correlated and marginal costs are not too high. Subsequent studies (Schmalensee (1984), McAfee, McMillan, and Whinston (1989), and Wilson (1993) etc.) find that the negative correlation is not a necessary condition. They argue that bundling leads to higher firm profits than unbundling even when demand are separable, or when preferences across products are nonnegative or independent. While these studies clearly show that bundling in a monopoly market is likely to increase firm profit, they fail to reach consensus on whether bundling increases consumer surplus and or social welfare. Adams and Yellen (1976) find that bundling decreases social welfare by causing distributive[3] and allocative inefficiency relative to unbundling. Bakos and Brynjolfsson (1999) find that bundling will always reduce consumers' surplus in a market with independent linear demand for multiple products. Crawford (2005) tests empirically the discriminatory hypothesis of bundling in the cable television industry under two-part tariffs, and finds that bundling can lead to six percent increase in firms' profits and more than five percent reduction in consumer surplus. Reisinger (2004), however, finds that bundling may increase consumer surplus under a duopoly market, where consumers' preferences are negatively correlated. Schmalensee (1982) and Salinger (1995) conclude that welfare impacts of bundling can go either direction subject to different conditions.

In this paper we study the impacts on both firm profit and consumer surplus under product bundling and three-part tariffs. A recent bundling practice in the wireless industry is to combine voice calls and SMS text messages[4], both offered by the same firm, into a service plan. Under such service plan, consumers pay an access fee of A per month that entails them to free usage of up to, F_1 and F_2 of voice calls (in minutes) and text messages (in number of messages) respectively. Above these amounts consumers will have to pay marginal prices of p_1 and p_2 for voice calls (per minute) and text messages (per message) respectively. Figure 1 describes the total payment for a user under such a pricing scheme. We use a unique panel dataset provided by a wireless company in a Chinese city. The purpose of this paper is to explore consumers' choices among several service plans and how the structure of the consumer preferences for multiple services would imply the optimal pricing mechanism under product bundling. More importantly, we study the impacts of this pricing scheme on different consumer segments in terms of consumer choices and usage patterns as well as consumer surplus and firm revenue. Hence, our research leads to a better understanding of the managerial and policy implications of the pricing scheme when the market consists of heterogeneous consumers.

---

[3] Distributive inefficiency is caused by oversupply of both commodities, undersupply of both commodities, or oversupply of one and undersupply of the other.

[4] SMS is a feature that allows users to receive and transmit short text message using their wireless phones (see www.wirelessadvisor.com).

We are not aware of any theoretical or empirical studies of three-part tariffs in a world where firms sell bundles of products or services. Since bundling and three-part tariff pricing have become more and more popular in many industries it is important for firms and policymakers to understand the impacts of bundling on firm profits and consumer surplus under such pricing schemes. Unfortunately, many results from previous literature cannot be applied to this situation. For instance, the majority of previous literature on product bundling assumes discrete demand, where consumers can only choose zero or one unit of each product. This assumption substantially simplifies the bundling models but at the cost of precluding the study of three-part tariffs where consumers may choose multiple units of products (Mitchell and Vogelsang (1991)). In this research we provide an empirical examination of bundling under a three-part pricing scheme allowing for continuous demand.

There are a few empirical studies of the impacts of three-part pricing when the seller sells a single product. For instance, Iyengar (2005) shows that the access fee affects consumer churn more than the marginal price. Lambrecht, Seim and Skiera (2005) find that demand uncertainty drives consumers' choice among three-part tariffs. They also find that access fee has a larger impact on choice of a plan than the marginal price or the free allowance. When the firm in our data sells multiple services consumers' service plan choices will depend on the expected usages of the multiple services which may be correlated. Taking account of this correlation is important for a firm's pricing decisions. Should the firm offer a bundle of services, or sell them separately, or both? What is the optimal pricing scheme for such service bundles? How will varying the free allowances and marginal prices for each service within a bundle affect consumers' plan choice and usage decisions? How will the above factors affect consumers' welfare and firm's profits?

To answer the above research questions we develop a structural demand model to explain consumers' plan choice and usage decision of service bundles. An important feature in our data is that a new service plan was introduced in the middle of the sample period attracting a number of new consumers. The new service plan and the existing service plan offer identical services but use different pricing schemes. In order to explain the observed dynamic patterns of consumer switching patterns (i.e., drop out from the service provider altogether, join in as new users, or switch between service plans), we include three important components in our model:

First, we model the switching cost consumers incur when they switch. It is widely recognized in the literature that consumer switching cost is one of firms' important strategic elements to retain consumers (Porter 1980, 1985; Klemperer 1995, Lieberman and Montegomery 1988, Kolter 1997 etc.). Although there is no explicit switching fee charged by the firm, implicit switching cost does exist. Iyengar (2005) finds that consumers may not choose the best service plan or switch to the best plan due to inertia. Epling (2002) shows that inherent switching cost is an important factor in subscribers’ switching decision to another service provider. In terms of switching among different service plans offered by the same firm, consumers incur search and transaction costs (e.g. the time and effort to arrange for the switching). Moshkin and Shachar (2002) find that switching cost can account for stickiness in plan choice. For firms the existence of switching cost has implications for customer relationship management. For example, one way to increase switching cost is through loyalty programs (Kotler 1997). Regulators often make inference about market power based on the existence of significant switching costs.

Second, we assume that consumers are uncertain about their preferences for voice call and text message. To allow for consumers to learn about their preference weights for these, we propose a learning model. Many previous empirical studies have examined consumer learning (see Erdem and Keane (1996), Ackerberg (2002), Crawford and Shum (2002), Coscelli and Shum (2004) and Narayanan, Chintagunta and Miravete (2005)). We find from our data that some consumers stay on the same plan for the entire period even when they would have been better off switching to the new plan, while others switch. We believe that it is important to incorporate both switching costs and consumer learning in explaining these differential switching behaviors.

Third, we explicitly account for the time lag between plan choice decision and usage decision. At the time of choosing a service plan consumers form expectations about their usage level based on prior beliefs. However, during learning consumers' beliefs about their preferences for voice call and text message could be different from the true preferences. Moreover their actual usages can be higher or lower than what their true preferences would imply due to exogenous shocks. It is important to understand how usage uncertainty will affect consumers' service plan services (for examples see Train, Ben-Akiva and Atherton 1989 and Lambrecht, Seim and Skiera 2005.)

To conclude, our research objectives are the following:

1. To examine the underlying consumer preference structure for product bundles under the three-part tariff pricing scheme.
2. To model the impact of switching costs and consumer learning on the choice of service plans and switching behaviors.
3. To provide managerial and welfare implications for the firm's product bundling and pricing schemes under different consumer preference structures.

From our estimation we find that consumer preferences for voice calls and text messages are positively correlated. Compared to a base model, by incorporating both switching costs and consumer learning our model can better explain the observed switching patterns after the new service plan was introduced in our data. Based on the model estimates, we conduct policy experiments to understand how different pricing schemes will affect consumers' service plan choices, usage decisions and their surplus, as well as the consumer surplus and firm profit. We find "better" pricing schemes which will significantly improve the firm's expected revenue, compare with the current pricing scheme, but will lower the expected consumer surplus. Compared with two-part tariffs, three-part tariffs when optimal prices are set improve the firm revenue as well as the consumer surplus. Comparing with the unbundling cases, we find that the firm expected revenue will be higher but consumer surplus will be lower, a result consistent with most previous literature on the use of product bundling in extracting consumer surplus. Interestingly, we find that under our computed optimal three-part tariff schemes the firm should offer one plan without any free usages, which is virtually two-part tariff. The purpose of offering a three-part tariff plan is to attract low preferences consumers, who will not join in without such a plan. Those with high preferences for voice calls and text messages will choose the two-part tariff plan.

The above results are based on the estimation result of positive correlation between consumer preferences for voice call and text message. To check how robust our experiment results are we further conduct a counter-factual policy experiment, where we assume that the consumer preferences are negatively correlated. In this case we find that under the optimal pricing scheme the firm will offer one service plan with free voice call usage, targeting consumers with a high preference for voice calls, and another plan with free text message usage, targeting consumers with a high preference for text messages. This implies that optimal prices may be different under different consumer preference correlations; hence, it demonstrates the importance of using structural modeling approach in our paper to infer the consumer preference structure.

The rest of the paper is organized as follows. Section 2 discusses the bundling and pricing practices in the wireless service industry and the data. Section 3 presents our structural demand model. Section 4 will first discuss the model estimation and then present estimation results. Section 5 presents the policy experiments results, and finally Section 6 concludes.

2. Data

Service bundling is a common practice in the wireless industry. A wireless service plan in general includes local call, long distance call that covers both domestic and international, SMS message, GPRS[5], and other features such as call waiting, caller ID, three-way calling, call forwarding, and coloring ring back tones. Some sub-bundles may exist in each of these service components. For example, a

[5] GPRS (General Packet Radio Service) is an emerging technology standard for high speed data transmission over GSM networks. (www.wirelessadvisor.com)

voice call is a bundle of on-net and off-net calls.[6] SMS messages are also bundles of on-net and off-net SMS messages. To simplify the analysis, we only focus on the two most popular services, local voice calls and SMS text messages, in this study.

As we discussed above, wireless services are generally sold under a three-part tariff nonlinear pricing scheme. This pricing scheme can be very complex that involves various amounts of free usages and marginal prices for numerous service components. A wireless service plan typically requires consumers to pay a monthly access fee with fixed quantities of free usages (allowances) for voice calls and text messages, followed by a positive marginal price once the usage is above the usage amount. Figure 1 illustrates the total payment scheme for a bundle of two services (voice calls and text messages, denoted as “1” and “2” correspondingly) under a three-part tariff. A subscriber first has to pay an amount of A each month in order to be able to use the services. Then she will be able to enjoy free usages F_1 and F_2 for the two services. Above these amounts she will have to pay a per unit price p_1 and p_2, respectively. As shown in the diagram the total cost the subscriber has to pay is highly non-linear depending on her usage decision for each of the services.

We collect a dataset with a sample of 2,357 consumers from a wireless service provider in a Chinese city. The dataset consists of individual-level monthly service plan choices and usage levels for local voice calls and SMS text messages from a cellular service provider, with a sample period from July 2003 to September 2005, altogether 25 months. Numerous service plans with different pricing schemes are offered by the service provider. In this study we only focus on the two most popular wireless service plans: “voice centric” and “data centric” plans. Table 1 provides some pricing details of the two plans. The voice centric plan charges different access fees to users based on the availability of roaming[7] (¥15 without and

[6] An on-net local call is a call that originates and terminates in the same network, and an off-net call is a call that originates and terminates in different networks provided by different firms. Since costs may be different between on- and off-net calls, a service provider with a larger network of subscribers usually has a competitive advantage in the market.
[7] Roaming allows users to use wireless phones in an area outside the coverage area. There is usually an additional charge for roaming. When the service provider's network has incomplete coverage, roaming arises. (www.wirelessadvisor.com)

¥30 with roaming[8], where Chinese dollar ¥1 is approximately equal to $0.125 in US dollar), while the data centric plan allows roaming for every user at a single access fee (¥20). The voice centric plan allows a higher voice call allowance but no text message allowance, while the data centric plan allows 300 free text messages a month. Above the free usage limits, marginal prices for both services are similar under the two plans, except that the data centric plan charges a lower price for off-net outgoing calls. Off-net incoming and outgoing marginal prices are higher than on-net prices for both voice calls and text messages because the service provider is charged an access fee or termination fee by local land-line phone firms or other service providers. Since we only have data on the total minutes of voice calls and number of text messages, we use the weighted average[9] of on- and off-net prices as the marginal prices for voice calls and text messages.

Two major wireless service providers co-exist in our city. The service provider in our data (Firm A) is the market leader with more than 60 percent of market share during the sample period (see Figure 2). Another major cellular competitor (Firm B) has a market share between 20 and 30 percent. The third company (Firm C) is the land-line provider in the city. Traditionally this land-line provider is not a competitor in the wireless market; however, it introduced a wireless fixed line service in March 2004. By subscribing to this service, consumers can carry their phones like a cell phone, and the incoming calls are free. This new service proved to be very successful, with the firm's wireless market share in the wireless industry increasing to about 12 percent at the end of the sample period. Because of the new competition, the market share of our service provider (Firm A) started to decline in 2004. As a response, the firm introduced in August 2004 a new data centric plan targeting consumers with higher demand for text messages. That proved to be a powerful competitive strategy. Its market share started to rebound since August 2004. As shown in Figure 3, the new plan gains new users quickly after its introduction. By the end of the sample period the number of its users has

[8] If a consumer on the voice centric plan uses roaming service in a particular month, he or she will pay ¥30 as monthly access fee; if not, he or she will only pay ¥15 as monthly access fee.
[9] This is computed by assuming balanced calling patterns, which implies that when a consumer makes a telephone call, the receiver of the call can be any other consumer with equal probability independent of his(her) current subscribed network.

almost caught up with the voice centric plan, the most popular plan of the firm which also grows steadily during our sample period.[10] This implies that, for the data centric plan, to attract new users and grow market share is at least as important as to induce switching between service plans among the existing users. Therefore, unlike most of the previous studies (e.g., Lambrecht, Seim and Skiera (2005) do not consider join-ins during the sample period, and Narayanan, Chintagunta and Miravete (2005) only consider switchers between plans), it is important for us to model why new users join in (whose usage before join-in is unobserved from data) and why existing users drop out from (whose usage after drop-out is unobserved from data) the service plans.

To understand the usage behavior difference among users, we break down the whole user sample into (i) those who stay on the voice centric plan and never switch, (ii) those who join in the new data centric plan and then stay, (iii) those who switch from the voice centric plan to data centric plan, (iv) those who join in the data centric plan and then switch to the voice centric plan, and (v) those who drop out from the firm's plans. Table 2 reports some summary statistics of the usages for both voice calls and text messages. While the average usage of voice calls is not significantly different across groups of users, the average usage of text messages for those who stay on the voice centric plan is significantly lower than other groups. The usages of switchers from the data centric to the voice centric plan and drop-outs are also lower than those who stay with or switch from voice centric to data centric plan. Nevertheless, we note that usages are endogenous which depend on free usages and marginal prices under different plans. Usage differences may reflect either different inherent consumer preferences or different pricing schemes.

To investigate whether or not consumers adjust their usage patterns and whether or not they gain from switching, we look at those switchers observed from data. We compute the consumer costs under the voice centric and data centric plans, respectively, based on different usage patterns. First, there are 131 users in our data switching from the voice centric plan to the data centric plan. Based on the

[10] Because of the growing acceptance of cellphone total market demand in the city grew over time during the sample period. As a result, number of users for both plans and for the three firms in the city also grew overtime.

observed usage patterns after they switch[11], 78 percent gain from switching with an average saving of ¥16.2, and 22 percent are worse off from switching with an average loss of ¥3.8. The average cost saving is ¥11.7 among all users. However, based on the usage pattern before they switch,[12] only 60 percent gain from switching with an average saving of ¥10.5, and 40 percent lose from switching with an average loss of ¥3.85. The average cost saving is ¥4.69. Figure 4 illustrates the average gain and loss based on the two usage patterns. There are similar gain and loss patterns among those users who switch from the data centric to the voice centric plan. This implies that consumers are on average making correct switching decisions. Moreover, consumers will change their usage patterns once they switch to another plan with different prices.

We are concerned with two issues related to the switching pattern here. First, again look at Figure 3. The market share of the new data centric plan grows gradually in the 12 months after it was introduced. This suggests that it takes time for users to realize the true benefits of joining in or switching to the new plan. As will be discussed in the next section, we propose a consumer learning model to explain this dynamic pattern of switching. Second, though we find that most switchers seem to make correct switching decisions, there are users who choose to stay with either voice centric or data centric plan but could have been better off if they switch. For example, among the 965 users who choose to stay with the voice centric plan, 25 percent of them would be benefited had they switched to the data centric plan, with an average saving of ¥5.04.[13] Moreover, there are some switchers from the voice centric plan to the data centric plan incurring losses but choosing to stay with the new plan. Why don't these consumers switch to a different service plan? A consumer learning story may not be sufficient to explain the fact that so many users choose to stay with the existing plan after 12 months of the introduction of the new plan. As we have discussed in the Introduction, we will rationalize this phenomenon by explicitly allowing for consumer switching costs (both from

[11] This provides an approximate upper bound on the savings of switching to the data centric plan.
[12] This can be viewed as a lower bound on the savings of switching to the data centric plan.
[13] Similarly, among those 728 users who join in and stay with the data centric plan until the end of sample period, about 15 percent of them would be better off had they switched to the voice centric plan, with a saving of ¥4.79.

switching between service plans provided by the same firm, or joining in or dropping out from the firm) in our model.

We randomly select 564 consumers from the above 2,357 consumers in our model estimation. This selected sample consists of 6,774 monthly observations, with 55 percent stay with the voice centric plan, and 45 percent with the data centric plan, at the end of the sample period. We compare the usage and switching patterns of this sub-sample and find them very similar to that of the whole sample.

3. The Model

In this section we will first discuss the direct utility function of using voice calls and text messages usages. Then we will explain how we model the consumer preference heterogeneity. With these the optimal conditions for usages, conditional on service plan choices will be derived. Based on these optimal usage conditions we can further derive the indirect utility functions for choosing service plans when consumers can only form expectations about their usages in any period, and hence the choice probability of each service plan. We will also explain in detail how switching costs and consumer learning are incorporated in our model.

3.1 The Utility Function

We model consumers' decisions regarding the wireless service in an integrated framework: consumers first choose the service plan including an outside option[14] and then, conditional on the service plan choice, make the usage decisions. While the service plan choice is a discrete decision, usage decisions are continuous. This set-up is analogous to the discrete/continuous demand model (for examples see Hanemann (1984) and Dubin and McFadden (1984)[15].) with the difference that we also account for the time lag between the plan choice and usage decisions (e.g., see Iyengar (2004) and Narayanan, Chintagunta and Miravete (2005)), where in each stage consumers’ information sets may be different.

[14] The outside option includes the choice of not having any wireless services and the choice of other competing wireless service providers. We cannot differentiate them from our data.
[15] Also for recent empirical works see Hendel (1999), Kim, Allenby and Rossi (2002), Dube (2004) and Chan (2005).

We assume that consumers' utility is derived from both using voice calls and text messages. Consumer *i*, *i=1, …, N*, chooses a service plan from the available wireless service plan options at time t. Consumer *i* has four options: stays in the same plan as time $t-1$, switches to another service plan within the same service provider, drops out of the existing service plans (i.e., choose the *outside* option), and signs in for one of the service plans as a new user. If she chooses an *inside* service plan from our service provider, indexed by $j=1,...,J$, at time *t*, she will then choose the number of voice call minutes x_{it}^{V}, the number of text messages x_{it}^{D}, and quantity of the outside good x_{it}^{0} other than the wireless services. To consume a wireless service bundle $\left\{x_{it}^{V}, x_{it}^{D}\right\}$, the consumer pays an access fee A_j, enjoys a free usage for voice calls F_j^V and for text messages F_j^D, and then pays a marginal price for voice calls p_j^V if $x_{it}^{V} > F_j^V$, and for text messages p_j^D if $x_{it}^{D} > F_j^D$. For model estimation we normalize the price of the outside good to 1. We allow for the case that the consumption of either voice calls or text messages may be zero in some periods, that is, corner solutions for usages may exist.

We assume that the consumer utility is additively separable in using voice calls and text messages.[16] The proposed utility structure, if consumer *i* chooses an inside service plan *j*, follows the following specification:

$$U_j^i\left(x_{it}^0, x_{it}^V, x_{it}^D\right) = \delta_j + x_{it}^0 + \left[\theta_{it}^V \beta_i^V x_{it}^V - \beta_i^V \frac{\left(x_{it}^V\right)^2}{2}\right] + \left[\theta_{it}^D \beta_i^D x_{it}^D - \beta_i^D \frac{\left(x_{it}^D\right)^2}{2}\right] + \varepsilon_{ijt} \quad (1)$$

where $U_j^i(\cdot)$ is the consumer's direct utility function, and δ_j is a plan-specific preference intercept representing benefits other than voice calls and text messages offered by the plan that are not modeled here. For simplicity we assume the

[16] We note that such additive separability assumption may restrict the substitution pattern among the two service usages. A more flexible specification will be to allow an interacting term between the voice call and text message usages in the utility function. However, since there is no price variation for each service plan during our sample period, such an interaction is difficult to be identified from our data. Furthermore, as will be discussed below, we allow the consumer preferences for voice calls and text messages to be correlated. Therefore our model is able to generate a flexible substitution pattern among the two service plans at the aggregate level.

intercept is homogeneous to all consumers. The marginal utility derived from the outside good x_{it}^{0} is normalized to 1. The sub-utility function $\theta_i^V \beta_i^V x_{it}^V - \beta_i^V \left(x_{it}^V\right)^2 \big/ 2$ is derived from voice call consumption and $\theta_i^D \beta_i^D x_{it}^D - \beta_i^D \left(x_{it}^D\right)^2 \big/ 2$ from text message consumption. Note that this additive separability structure implies neither complementarity nor substitutability between using voice calls and text messages, and the utilities from using voice calls and text message are independent of the utility from consuming the outside good. Parameters to be estimated include δ_j , θ_{it}^V , θ_{it}^D , β_i^V and β_i^D , where the last two parameters are restricted to be positive. The last component in (1) ε_{ijt} is the individual-, plan- and period-specific *i.i.d.* random shock that will affect consumers' service plan choices but unobserved to researchers. The quadratic sub-utility functions with positive β_i^V and β_i^D imply that consumers are risk averse and there is a satiation point in usage[17].

3.2 Preference Heterogeneity

We assume that consumers' preference parameter for using voice calls and text messages, $\theta_{it}^L = \left\{\theta_{it}^V, \theta_{it}^D\right\}$, has two components. First there is an individual-specific and time-invariant preference component θ_i^L , and then an individual- and time-specific *i.i.d.* unobserved preference shock ξ_{it}^L . That is,

$$\theta_{it}^L = \theta_i^L + \xi_{it}^L, L = \{V, D\} \tag{2}$$

Let $\theta_i \equiv \begin{pmatrix} \theta_i^V \\ \theta_i^D \end{pmatrix}$. We assume that $\theta_i \sim normal(\begin{pmatrix} \bar{\theta}^V \\ \bar{\theta}^D \end{pmatrix}, \Sigma_\theta)$, and $\Sigma_\theta = \begin{bmatrix} \sigma_V^2 & \sigma_{VD} \\ \sigma_{VD} & \sigma_D^2 \end{bmatrix}$. This set-up implies that the consumer preferences for using voice calls and text messages may be correlated. We also assume the time-varying unobserved preference shocks $\xi_{it} \equiv \begin{pmatrix} \xi_{it}^V \\ \xi_{it}^D \end{pmatrix} \sim_{i.i.d.} normal(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \Sigma_\xi)$, where $\Sigma_\xi = \begin{bmatrix} \sigma_\xi^{V2} & \sigma_\xi^{VD} \\ \sigma_\xi^{VD} & \sigma_\xi^{D2} \end{bmatrix}$. This allows for the correlation in time-varying preference shocks for using voice

[17] This quadratic utility specification is consistent with previous literature such as Wilson (1992), Miravete (2002), Miravete and Roller (2003), Jensen(2004), Iyengar (2004) and Economides, Seim and Viard (2005).

calls and text messages. The time-varying and individual-specific preference shocks ε_{ijt} in (1) are assumed to be *i.i.d.* with double exponential distribution.

Finally, as we will show below, β_i^V and β_i^D in (1) directly correlate with usage responsiveness to changes in marginal prices p_j^V and p_j^D, respectively. Because there is no price variation within each service plan in our data, consumer heterogeneity of usage responsiveness is hard to be identified. We impose the homogeneity assumption that $\beta_i^V = \beta^V$ and $\beta_i^D = \beta^D$ for all consumers.

3.3 Usage Decisions

We start with the consumer usage decisions for both voice calls and text messages, conditional on choosing a service plan *j*. We assume that at this stage the consumer preferences for voice calls and text messages, θ_{it}^V and θ_{it}^D, are realized, as opposed to the service plan choice stage when consumers can only form expectations, which we will explain in later section. However, the consumer cannot separate θ_i from ξ_{it}. That is, she only knows her preferences in period *t* but does not know for sure how much will remain unchanged and how much may fluctuate over time. We assume that the consumer chooses usages that will maximize her utility subject to a budget constraint. The direct utility maximization problem is specified as

$$\begin{aligned} &\max_{\left\{x_{it}^0, x_{it}^V, x_{it}^D\right\}} U_j^i\left(x_{it}^0, x_{it}^V, x_{it}^D \mid d_{it} = j\right) \\ &s.t.\ x_{it}^0 + \left[p_j^V \cdot \left(x_{it}^V - F_j^V\right)\right]\left\{x_{it}^V \geq F_j^V\right\} + \left[p_j^D \cdot \left(x_{it}^D - F_j^D\right)\right]\left\{x_{it}^D \geq F_j^D\right\} + A_j \leq Y_i \end{aligned} \tag{3}$$

where $U_j^i(\cdot)$ is consumer i's direct utility in (1) conditional on choosing plan *j*, d_{it} is the discrete service plan choice at time *t*, and $\left\{x_{it}^0, x_{it}^V, x_{it}^D\right\}$ are the endogenous usage decisions for the outside good, voice calls, and text messages, respectively. F_j^V and F_j^D are the corresponding free usages for local voice calls and text messages, and A_j is the access fee, p_j^V and p_j^D are marginal prices for voice calls and text messages, and Y_i is the income of the consumer. Finally $\{\cdot\}$ in the second line in (3) is an indicator function which is equal to one if the logical expression inside is true, and zero otherwise. The consumer will be charged by the marginal prices only if her usage exceeds the number of free minutes or the number of free text messages in the plan. If she chooses the voice-centric plan in our data, there is no free usage for text messages in the service plan, therefore $F_j^D = 0$. Solve for (3) we have the following Kuhn-Tucker conditions for optimal usage of voice calls (x_{it}^{V*}) and text messages (x_{it}^{D*})[18]:

$$
\begin{aligned}
& x_{it}^{V*} \cdot (\theta_{it}^{V} - \frac{1}{\beta^{V}} \cdot p_j^V \cdot \left\{ \theta_{it}^{V} \geq F_j^V + \frac{1}{\beta^{V}} \cdot p_j^V \right\} - x_{it}^{V*}) = 0 \\
& x_{it}^{D*} \cdot (\theta_{it}^{D} - \frac{1}{\beta^{D}} \cdot p_j^D \cdot \left\{ \theta_{it}^{D} \geq F_j^D + \frac{1}{\beta^{D}} \cdot p_j^D \right\} - x_{it}^{D*}) = 0
\end{aligned}
\tag{4}
$$

Conditions (4) allow for the existence of corner solutions, i.e., $x_{it}^{V*} = 0$ or $x_{it}^{D*} = 0$. This is the case when either θ_{it}^{V} or θ_{it}^{D} are negative. Moreover, when $0 < \theta_{it}^{L} < F_j^L + \frac{1}{\beta^{L}} \cdot p_j^L$, *L=V or D* (hence the indicator functions in (4) are equal to zero), then $x_{it}^{L*} = \theta_{it}^{L}$; otherwise if $\theta_{it}^{L} \geq F_j^L + \frac{1}{\beta^{L}} \cdot p_j^L$ (hence the indicator functions in (4) are equal to one), $x_{it}^{L*} = \theta_{it}^{L} - \frac{1}{\beta^{L}} \cdot p_j^L$.

3.4 Service Plan Choices

Based on the direct utility function in (1) and the objective function in (3), we can plug in the Kuhn-Tucker conditions in (4) to derive an *indirect* utility function of choosing service plan *j* as the follows:

[18] Following convention we assume the there always exists an interior solution for the outside good consumption, i.e., $x_{it}^{0*} > 0$.

$$
\begin{aligned}
&V_{j,it}\left(A_j;F_j^V,F_j^D;p_j^V,p_j^D;Y_i\right)\\
&=\delta_j+\left[Y_i-A_j\right]+\frac{\left(\theta_{it}^V\right)^2\beta^V}{2}\cdot\left\{\theta_{it}^V>0\right\}+\frac{\left(\theta_{it}^D\right)^2\beta^D}{2}\cdot\left\{\theta_{it}^D>0\right\}\\
&\quad+\left[-\theta_{it}^V p_j^V+\frac{1}{2}\frac{1}{\beta^V}\left(p_j^V\right)^2+p_j^V F_j^V\right]\left\{\theta_{it}^V>F_j^V+\frac{1}{\beta^V}\cdot p_j^V\right\}\\
&\quad+\left[-\theta_{it}^D p_j^D+\frac{1}{2}\frac{1}{\beta^D}\left(p_j^D\right)^2+p_j^D F_j^D\right]\left\{\theta_{it}^D>F_j^D+\frac{1}{\beta^D}\cdot p_j^D\right\}\\
&\quad+\varepsilon_{ijt}
\end{aligned}
\tag{5}
$$

Interpretations of equation (5) are as follows: If both $\theta_{it}^V<0$ and $\theta_{it}^D<0$, the indirect utility function will be $V_{j,it}=\delta_j+\left[Y_i-A_j\right]+\varepsilon_{ijt}$; if both $0<\theta_{it}^V\le F_j^V+\frac{1}{\beta^V}\cdot p_j^V$ and $0<\theta_{it}^D\le F_j^D+\frac{1}{\beta^V}\cdot p_j^D$, we will have $V_{j,it}=\delta_j+\left[Y_i-A_j\right]+\frac{\left(\theta_{it}^V\right)^2\beta^V}{2}+\frac{\left(\theta_{it}^D\right)^2\beta^D}{2}+\varepsilon_{ijt}$; finally if both $\theta_{it}^V>F_j^V+\frac{1}{\beta^V}\cdot p_j^V$ and $\theta_{it}^D>F_j^D+\frac{1}{\beta^D}\cdot p_j^D$, we will have

$$
\begin{aligned}
V_{j,it}=\delta_j+\left[Y_i-A_j\right]&+\frac{\left(\theta_{it}^V\right)^2\beta^V}{2}-\theta_{it}^V p_j^V+\frac{1}{2}\frac{1}{\beta^V}\left(p_j^V\right)^2+p_j^V F_j^V\\
&+\frac{\left(\theta_{it}^D\right)^2\beta^D}{2}-\theta_{it}^D p_j^D+\frac{1}{2}\frac{1}{\beta^D}\left(p_j^D\right)^2+p_j^D F_j^D+\varepsilon_{ijt}
\end{aligned}
$$

The indirect utility function of choosing service plan *j* depends on the consumer preferences for using both voice calls and text messages.

If consumer *i* chooses the outside option, we assume an indirect utility function as follows:

$$V_{0,it}=\delta_0+Y_i+\varepsilon_{i0t} \tag{6}$$

In the estimation model δ_0 is normalized to 0 for model identification. We assume that ε_{i0t} is independently and identically distributed with double exponential distribution.

The consumer makes the service plan choice at the beginning of period *t*. As opposed to the usage decisions in (4), she does not exactly know the value of θ_{it}^{L}, where L=V or D (see equation (2)), which consists of a time-varying idiosyncratic demand shock ξ_{it}^{L} whose value the consumer only knows the distribution, and a time-invariant preference type θ_{i}^{L} that she can only learn gradually over time (we will further discuss in the learning model later). The consumer has to form an expectation for $V_{j,it}$ based on her past usage history or information set Ω_{it}, i.e., $E[V_{j,it} | \Omega_{it}]$. The consumer will choose the option with the highest *expected* indirect utility.

The new data centric plan was introduced in the middle of the sample period. Before the new plan is available, consumers' consideration set consists of the existing voice centric plan and the outside option. After the new plan is available, consumers' consideration set now consists of the voice centric plan, the data centric plan and the outside option.[19]

3.5 Switching Costs and Learning

To explain the dynamic switching or non-switching patterns observed among consumers, we allow for the existence of switching costs and consumer learning of their own preference types in our model. First, we assume that consumer i incurs switching cost, SC_{i}^{1}, when she switches to a different service plan provided by the same firm, which is distributed as $normal\left(SC^{1}, \sigma_{sc^{1}}^{2}\right)$. If the consumer decides to drop out or join in from the outside option, it incurs another switching cost, SC^{2}. For identification issue we restrict this cost to be homogeneous across consumers. As discussed before, switching between service plans within a firm may incur a different cost, either physically or psychologically, compared to switching between firms.

[19] We ignore in our model that some consumers may not be aware of the existence of the new service plan, i.e., the new plan is not in their consideration set. Though it may take time for consumers to learn the existence of the service plan, such a learning process is difficult to be identified from our data, especially that it cannot be distinguished from the process of consumers learning own usage preferences, which is modeled in the paper.

Suppose the consumer is a user of the voice centric plan (plan 1) in period *t-1*. In period *t*, she will again choose the same plan, instead of the data-centric plan (plan 2) or the outside option, if the following is true:

$$E[V_{1,it} \mid \Omega_{it}] \geq \max\left\{E[V_{2,it} \mid \Omega_{it}] - SC_i^1, V_{0,it} - SC^2\right\},$$

Based on the double exponential distribution assumption for plan choice shocks $\left(\varepsilon_{i1t}, \varepsilon_{i2t}, \varepsilon_{i0t}\right)$ the choice probability for service plan 1 in period t is

$$\begin{aligned}
&\Pr_i\left(d_{it} = 1\right) \\
&= \Pr\left\{\left(\varepsilon_{i1t}, \varepsilon_{i2t}, \varepsilon_{i0t}\right):\ E\bar{V}_{1,it} + \varepsilon_{i1t} \geq \max(E\bar{V}_{2,it} - SC_i^1 + \varepsilon_{i2t}, \bar{V}_{i0} - SC^2 + \varepsilon_{i0t})\right\} \qquad (7) \\
&= \frac{\exp\left(E\bar{V}_{1,it}\right)}{\exp(\bar{V}_{i0} - SC^2) + \exp\left(E\bar{V}_{1,it}\right) + \exp\left(E\bar{V}_{2,it} - SC_i^1\right)}
\end{aligned}$$

where d_{it} is the discrete service plan choice of consumer i in period t, $E\bar{V}_{j,it}$ is the deterministic part in $E[V_{j,it} \mid \Omega_{it}]$ without the idiosyncratic component ε_{ijt}, and $\bar{V}_{i0}$ is similarly defined.

Similarly, the consumer will switch to service plan 2 if the following condition is true:

$$E[V_{2,it} \mid \Omega_{it}] - SC_i^1 \geq \max\left\{E[V_{1,it} \mid \Omega_{it}], V_{0,it} - SC^2\right\}$$

And she will choose to drop out if

$$V_{0,it} - SC^2 \geq \max\left\{E[V_{1,it} \mid \Omega_{it}], E[V_{2,it} \mid \Omega_{it}] - SC_i^1\right\}$$

with choice probabilities similar to equation (7).

If the consumer is not a user of our service provider in period *t-1*, by joining either plan 1 or 2 she will incur switching cost SC^2. Hence, she will only choose service plans 1 or 2 if either

$$E[V_{1,it} \mid \Omega_{it}] - SC^2 \geq \max\left\{E[V_{2,it} \mid \Omega_{it}] - SC^2, V_{0,it}\right\}$$

or

$$E[V_{2,it} \mid \Omega_{it}] - SC^2 \geq \max\left\{E[V_{1,it} \mid \Omega_{it}] - SC^2, V_{0,it}\right\}$$

is true, respectively. Based on that choice probabilities of joining can be derived similarly as equation (7). We will discuss how we compute $E\bar{V}_{j,it}$ in detail later.

Consistent with most previous literature on learning, we allow that consumers may not know their own time-invariant preference types $\{\theta_i^V, \theta_i^D\}$ hence have to form expectations based on past experiences. This type of consumer learning is important in explaining why in our data consumers only switched to the new data centric plan several periods after the plan had been introduced (and some did not switch at all) even when their savings are large had they switched earlier. At the end of each period, consumer *i* observes her own usages x_{it}^V and x_{it}^D. Suppose these usages are positive, the optimal conditions of usages imply that

$$\begin{aligned} \theta_{it}^V &= \theta_i^V + \xi_{it}^V = x_{it}^V + b^V p_j^V \cdot \left\{ \theta_{it}^V > F_j^V + \frac{1}{\beta^V} \cdot p_j^V \right\} \\ \theta_{it}^D &= \theta_i^D + \xi_{it}^D = x_{it}^D + b^D p_j^D \cdot \left\{ \theta_{it}^D > F_j^D + \frac{1}{\beta^D} \cdot p_j^D \right\} \end{aligned} \tag{8}$$

where $b^L = 1/\beta^L$, $L=V$ or D. Though there is a one-to-one mapping between usage x_{it}^L and the time-varying preference θ_{it}^L (we assume that b^L is known to the consumer) so that she can use the observed usages to infer preferences, she cannot separate θ_i^L and ξ_{it}^L from the sum θ_{it}^L. We assume that the consumer knows that (ξ_{it}^V, ξ_{it}^D) are distributed as $N\left(0, \Sigma_\xi\right)$. Regarding θ_i^L, we assume that in the first period *t=1* all consumers have the same prior beliefs distributed as $\begin{pmatrix} \theta_i^V \\ \theta_i^D \end{pmatrix} \sim N\left(\begin{pmatrix} \theta_0^V \\ \theta_0^D \end{pmatrix}, \Sigma_{\theta 0}\right)$, where $\begin{pmatrix} \theta_0^V \\ \theta_0^D \end{pmatrix}$ represents the prior preference means, and $\Sigma_{\theta 0} = \begin{bmatrix} \sigma_0^{V2} & 0 \\ 0 & \sigma_0^{D2} \end{bmatrix}$ is the prior variance-covariance matrix which measures the consumer uncertainty.[20] At the end of every period, after observing their usages, consumers update the beliefs of their preference types using the Bayesian rule

[20] For the simplicity of model estimation we assume that consumers believe that their preferences for voice calls and text messages are independent. It is generalizable to the case when preferences in prior beliefs are not independent.

(Degroot (1970)): Assuming after t periods the consumer's belief of her preference type for using service L is $N\left([\theta_{i,t}^{V}\ \ \theta_{i,t}^{D}]',\Sigma_{\theta_i,t}\right)$ [21], then her belief at time $t+1$ are distributed as $N\left([\theta_{i,t+1}^{V}\ \ \theta_{i,t+1}^{D}]',\Sigma_{\theta_i,t+1}\right)$ where $[\theta_{i,t+1}^{V}\ \ \theta_{i,t+1}^{D}]'$ and $\Sigma_{\theta_i,t+1}$ are given by

$$\begin{aligned}&\begin{pmatrix}\theta_{i,t+1}^{V}\\ \theta_{i,t+1}^{D}\end{pmatrix}=\Sigma_{\theta_i,t+1}\left(\left(\Sigma_{\xi}\right)^{-1}\begin{pmatrix}x_{it}^{V}+b^{V}p_j^{V}\\ x_{it}^{D}+b^{D}p_j^{D}\end{pmatrix}+\left(\Sigma_{\theta_i,t}\right)^{-1}\begin{pmatrix}\theta_{i,t}^{V}\\ \theta_{i,t}^{D}\end{pmatrix}\right).\\ &\Sigma_{\theta_i,t+1}=\left(\left(\Sigma_{\xi}\right)^{-1}+\left(\Sigma_{\theta_i,t}\right)^{-1}\right)^{-1}\end{aligned}\qquad (9)$$

Zero usages, though infrequent, do exist for either voice calls or text messages in the data. When the consumer experiences, say, $x_{it}^{V}=0$, she can only infer that $\theta_{it}^{V}\le 0$ at time *t*. The updated belief for θ_i^{V} will follow the prior belief distribution at time *t* conditional on the truncated usage, i.e.,

$$N\left(\theta_{i,t}^{V},\sigma_{i,t}^{V\,2}\,|\,\theta_i^{V}+\xi_{it}^{V}\le 0\right)\qquad (10)$$

where $\theta_{i,t}^{V}$ and $\sigma_{i,t}^{V\,2}$ are the mean and variance in prior beliefs for θ_i^{V} at time *t*, respectively. In model estimation we simulate this conditional distribution to obtain the estimates for $\theta_{i,t+1}^{V}$ and $\sigma_{i,t+1}^{V\,2}$.

4 Estimation Results

4.1 Some Details for the Estimation Model

The optimal conditions for voice call and text message usages in equation (4) imply a Tobit-type regression: If the observed usages x_{it}^{L}, *L*=*V* or *D*, is positive, we can derive that $\theta_i^{L}+\xi_{it}^{L}=x_{it}^{L}+\dfrac{1}{\beta^{L}}\cdot p_j^{L}\cdot\left\{x_{it}^{L}\ge F_j^{L}\right\}$. If $x_{it}^{L}=0$, we can infer that $\theta_i^{L}+\xi_{it}^{L}\le 0$. Conditional on $(\theta_i^{V},\theta_i^{D})$, we can write down the probability function of the observed usages (x_{it}^{V},x_{it}^{D}) as $\Pr(x_{it}^{V},x_{it}^{D}\,|\,\theta_i^{V},\theta_i^{D})$, following our assumption that the idiosyncratic preference shocks $(\xi_{it}^{V},\xi_{it}^{D})$ are distributed as $N\left(0,\Sigma_{\xi}\right)$. Note that θ_i^{L} here is the true preference of consumer *i* and not the prior belief because the

[21] Here the subscript "t" denotes consumers' beliefs of own preference types after period t.

true value has been realized in the usage decision stage. In the model estimation, we simulate the *unconditional* probability function of usages by using a frequency simulator for $\begin{pmatrix}\theta_i^V\\ \theta_i^D\end{pmatrix}$: Let *s* represents a simulation. We draw, for each consumer *i*, $\begin{pmatrix}\theta_{i,s}^V\\ \theta_{i,s}^D\end{pmatrix}$ from the assumed population distribution $N(\begin{pmatrix}\bar{\theta}^V\\ \bar{\theta}^D\end{pmatrix}, \Sigma_\theta)$ for *ns* times and fixed these simulated draws over time for each consumer. The simulated likelihood of the observed usages for consumer *i* from periods *t=1,…, T* is evaluated as the follows:

$$\Pr_i^s(x_{i1}^V, x_{i1}^D;...;x_{iT}^V, x_{iT}^D) = \frac{1}{ns}\sum_{s=1}^{ns}[\Pr(x_{i1}^V, x_{i1}^D \mid \theta_{i,s}^V, \theta_{i,s}^D)\cdot ... \cdot \Pr(x_{iT}^V, x_{iT}^D \mid \theta_{i,s}^V, \theta_{i,s}^D)]$$

Now turn to the likelihood function of service plan choices in each period. Equation (7) provides an example of the choice probability that a consumer chooses service plan *1* at time *t*. All other probability functions are similarly defined. The difficulty in actual model estimation comes from evaluating $E\bar{V}_{j,it}$, which is the deterministic part in $E[V_{j,it} \mid \Omega_{it}]$ without the idiosyncratic component ε_{ijt} (also see equation (5)). As opposed to evaluating the probability function for usages $\Pr(x_{i1}^V, x_{i1}^D;...;x_{iT}^V, x_{iT}^D)$, $E\bar{V}_{j,it}$ is a function of the consumer's beliefs of $\begin{pmatrix}\theta_i^V\\ \theta_i^D\end{pmatrix}$ and not her true preferences. Let $(\tilde{\theta}_{i,t}^V, \tilde{\theta}_{i,t}^D)$ be a pair of random variables that represent the consumer's beliefs of her true preference types at time *t*, with the distribution function $F(\tilde{\theta}_{i,t}^V, \tilde{\theta}_{i,t}^D) = N\left([\theta_{i,t}^V \;\; \theta_{i,t}^D]', \Sigma_{\theta_i,t}\right)$, where $[\theta_{i,t}^V \;\; \theta_{i,t}^D]'$ and $\Sigma_{\theta_i,t}$ are the updated means and variances of her preferences, respectively. $E\bar{V}_{j,it}$ can be written as the follows:

$$
\begin{aligned}
E\bar{V}_{j,it} &= \delta_j + \left[Y_i - A_j\right] \\
&+ \int \left(\begin{aligned}
&\frac{\left(\tilde{\theta}^V_{i,t} + \xi^V_{it}\right)^2 \beta^V}{2} \cdot \left\{\tilde{\theta}^V_{i,t} + \xi^V_{it} > 0\right\} + \frac{\left(\tilde{\theta}^D_{i,t} + \xi^D_{it}\right)^2 \beta^D}{2} \cdot \left\{\tilde{\theta}^D_{i,t} + \xi^D_{it} > 0\right\} \\
&+ \left[-\left(\tilde{\theta}^V_{i,t} + \xi^V_{it}\right) p^V_j + \frac{1}{2}\frac{1}{\beta^V}\left(p^V_j\right)^2 + p^V_j F^V_j\right]\left\{\tilde{\theta}^V_{i,t} + \xi^V_{it} > F^V_j + \frac{1}{\beta^V} \cdot p^V_j\right\} \\
&+ \left[-\left(\tilde{\theta}^D_{i,t} + \xi^D_{it}\right) p^D_j + \frac{1}{2}\frac{1}{\beta^D}\left(p^D_j\right)^2 + p^D_j F^D_j\right]\left\{\tilde{\theta}^D_{i,t} + \xi^D_{it} > F^D_j + \frac{1}{\beta^D} \cdot p^D_j\right\}
\end{aligned} \right) dF(\tilde{\theta}^V_{i,t}, \tilde{\theta}^D_{i,t}) dF(\xi^V_{it}, \xi^D_{it})
\end{aligned}
$$

The above expression, unfortunately, does not have a closed-form expression. To compute this function we again use the simulation method by drawing $(\tilde{\theta}^V_{i,t}, \tilde{\theta}^D_{i,t})$ from the prior belief distribution $N\left([\theta^V_{i,t}\ \ \theta^D_{i,t}]', \Sigma_{\theta_i,t}\right)$, and (ξ^V_{it}, ξ^D_{it}) from the assumed distribution $N(0, \Sigma_\xi)$ to form the simulated $E\bar{V}^s_{j,it}$ in the above expression. We then plug the simulated $E\bar{V}^s_{j,it}$, for every service plan *j*, every consumer *i*, and every period *t*, into the multinomial logit function analogous to equation (7) to become our service plan probability function, $\Pr^s_i\left(d_{it} = j\right)$.

We jointly estimate the likelihoods of both usage and service plan choice decisions. Let Θ be the vector of parameters including the utility function coefficients, switching costs and means and variances in prior beliefs. Our estimator $\hat{\Theta}$ satisfies the following condition:

$$
\hat{\Theta} = \arg\max_{\Theta} \prod_{i=1}^{N} \{\Pr^s_i(x^V_{i1}, x^D_{i1}; \ldots; x^V_{iT}, x^D_{iT} \mid \Theta) \cdot \prod_{t=1}^{T} \Pr^s_i\left(d_{it} = j \mid \Theta\right)\} \tag{11}
$$

Some more details for the model specification here: we assume that at time *t=1* all consumers have the same prior beliefs as $\begin{pmatrix}\theta^V_i \\ \theta^D_i\end{pmatrix} \sim N\left(\begin{pmatrix}\theta^V_0 \\ \theta^D_0\end{pmatrix}, \Sigma_{\theta 0}\right)$, where $\Sigma_{\theta 0} = \begin{bmatrix}\sigma^{V2}_0 & 0 \\ 0 & \sigma^{D2}_0\end{bmatrix}$. Parameters θ^V_0 and θ^D_0 are known to be difficult to be identified from data (for example see Chan and Hamilton (2006)); hence, we restrict them to be equal to $\bar{\theta}^V$ and $\bar{\theta}^D$, the population mean preferences for using voice calls and text messages, respectively. We also impose the restriction that σ_0^{V2} and σ_0^{D2} are equal to the variances of preferences among the population.

A unique feature in our data is that many new consumers join in (especially after the data centric service plan was introduced) and existing consumers drop out in different time periods. Usages of these consumers before join in or after drop out are not observed from data. In order to evaluate the probability of not joining in the service plans we have to make assumptions about their beliefs of own preferences. In the model estimation, we assume that these consumers maintain the same prior beliefs $N\left(\begin{pmatrix}\theta_0^V\\ \theta_0^V\end{pmatrix}, \Sigma_{\theta 0}\right)$ overtime until they join in. Then they will update their beliefs using the observed usages. After they drop out, we assume that they will maintain their updated beliefs right before they leave. An interpretation which makes the assumption of constant beliefs before join in or after drop out valid is that the outside option is not to use any cellular services hence consumers do not know what their usages would be had they subscribed to the service plans. The consumers' outside option choice before join in or after drop out is included in the likelihood function in (11). Though this assumption may be restrictive, we are not able to infer how beliefs are updated during these periods because of the lack of data. However, ignoring new join-ins or drop-outs consumers may create bias in the model estimation. Since one of our research purposes is to evaluate how the service provider may attract new customers or retain existing customers through introducing new service plans, we consider it important to correctly infer the relative value of the outside option available to the potential consumers.

Finally, we estimate three models: Model 1 is a base model which does not allow for switching costs or consumer learning. Model 2 is the model allowing for switching costs but no consumer learning. Model 3 is our proposed model which allows for both switching costs and consumer learning. Comparing these three models helps to shed light on the robustness of our estimation results. It is also useful in understanding how much better, by adding the components of switching costs and consumer learning, helps to explain the observed patterns of service plan switching, joining in and dropping out in our model.

4.2 Estimation Results

Estimation results are reported in Table 3. All of the three models suggest that, while the mean preference for using voice calls (*voice demand intercept*) is higher than the mean preference for using text messages (*message demand intercept*), there is a larger heterogeneity in text message preference (*standard deviation of message demand intercept*). The demand slopes for using both voice calls and text messages are significantly negative, suggesting that consumers do respond to marginal price changes in voice calls and messages. One of the unexpected results is that the voice call preference is positively correlated with messages preference (The estimated correlations are 0.029, 0.160 and 0.057 in three models.), implying that consumers who have a high voice call preference are also likely to have a high text message preference. Another unexpected result is that the voice call usage shock is also positively correlated with text message usage shock (parameter l_{12}). This estimate implies an estimated covariance of 0.374, 0.530 and 0.389 in three models (see footnote in the table), implying that consumers with a high voice call usage shock in a period are also likely to have a high text message usage shock. Although these results are counter-intuitive, they are consistent with our data. For example, we find that consumers who stay with or switch to the data centric plan have a higher usage for both voice calls and text messages, compared to those consumers who stay with or switch to the voice centric plan (see Table 2). Since the latter plan offers more free voice call minutes, such voice call usage difference should reflect differences in consumer voice call preferences instead of price differences. Such a finding has an important implication for the firm's pricing strategy for service bundles, which we will further explore in the later section.

Models 2 and 3 show that on average consumers, when they switch service plans within the service provider, incur a mean switching cost of ¥5.981 and ¥6.275 with standard deviations 0.794 and 0.98, respectively, and ¥6.4 when they switch to and from the outside option. This is consistent with our intuition that the latter switching should be more costly, either physically or psychologically, than the former. Furthermore, the small difference in the switching costs (from 10 to 40 cents) seems to imply that to most consumers the outside option is not to use any cellular services at all, since if it is switching between cellular companies consumers are required to change phone numbers and visit or call both companies, hence the switching cost should be much larger. Although overall the switching costs are small (less than US $1), it may not be unreasonable considering that the purchasing power of the Chinese consumers in our city is relatively low (e.g., compared with Americans). Taking into account of switching costs improves the model fit a lot (as likelihood value improves from -19,019 in Model 1 to -12,980 in Model 2), suggesting that switching cost is useful in explaining the choice patterns observed in the data. Allowing for consumer learning in Model 3 the likelihood further improves to -12,954. Since the numbers of parameters in Models 2 and 3 are identical, our learning model dominates other models in terms of sample fit. A further support for using our proposed model is to compare the predicted switching patterns from the models with data. According to the data there are 5.6% switchers who switch from voice-centric plan to data-centric plan. The predicted switching proportions are 13.4%, 2.8%, 4.1% according to Models 1, 2 and 3, respectively. This clearly shows that Model 3 has better explanatory power for the switching pattern in data.

Based on the results from our proposed Model 3, we compute some elasticities corresponding to how plan choice probabilities, voice call and text message usages, as well as the firm revenue, change with respect to changes in the pricing scheme including access fee, voice call and text message marginal prices, and free usages for voice calls and text messages.[22] The results are reported in Table 4.

First, when we compare the usage elasticities for both voice call and text message under the current voice-centric and data-centric plan pricing schemes, an interesting result is that the former is always more elastic than the latter. This implies that a one percent change in either access fee, marginal prices, or free

[22] We first compute the elasticities at the consumer-level, and then average all the individual elasticities.

usages will induce a much larger change in usages for the voice-centric plan. Note that the voice centric plan does not allow for free text message usage hence it is virtually a two-part tariff pricing scheme for text messages. Its larger text message usage elasticity is consistent with previous findings that usage demand is more elastic under two-part tariffs pricing scheme than three-part tariffs. The usage elasticities of voice call free usage we computed here are much smaller than the result in Lambrecht et al. 2005, perhaps due to the fact that in our data a large number of users consume above the allowance; hence, a small change in the number of free minutes may not significantly change the aggregate voice call usage.

Turn to the choice elasticities. Again we find that under the current pricing schemes demand for the voice-centric plans is more elastic than for the data-centric plan. Moreover, these choice elasticities are in general lower than the findings in Lambrecht, et al. 2005 and Narayanan et al. 2005, perhaps because our dataset comes from a different market (China) hence competition is different.

Finally, under the current pricing schemes the revenue elasticities as access fees or voice call marginal prices change are positive for both plans, while the elasticities as free usages change are negative. These elasticities are all significantly different from zero (simple economic theory tells us that a revenue-maximizer should set price at the zero revenue elasticity level). Moreover, overall the revenue elasticities under the voice-centric plan are larger in magnitude than under the data-centric plan. Does this imply that the firm set a sub-optimal pricing scheme for its existing service bundles? We should not reach a simple conclusion by looking at the elasticities, given that the firm is using two complicated three-part tariffs with product bundling. Instead of looking at the revenue impact separately, we have to simultaneously consider the impact of change in one component of a pricing scheme on other components within the same service plan, and the impact on the other service plan. Furthermore, as we find that voice call and text message preferences are positively correlated among consumers, will it be profitable at all for the firm to bundle voice call and text message in a service plan, as opposed to selling each separately? Finally, will it be possible to use our estimation results to find an optimal pricing scheme for the service bundles under three-part tariffs? We will further explore these issues in the following section.

5 Policy experiments

Our major purpose in conducting the policy experiment is to investigate whether the current pricing schemes maximize the firm profit and, if not, what are the "optimal" pricing schemes that the firm may adopt. We will compare the profit of the firm under the optimal three-part tariffs with two bundling plans to the profit under two-part tariffs with two bundling plans, and also to the profit levels in the unbundling cases where services are sold separately under two- or three-part tariffs. Comparison results will help us to better understand first how three-part tariffs may improve profitability over other pricing schemes such as two-part tariffs, and second how product bundling may improve profitability over the cases without bundling. Finally we also set up a counter-factual pricing experiment assuming a consumer preference structure different from the estimation results, with the purpose of studying how our optimal pricing policies should be modified when the consumer preferences have changed.

We assume that the firm is a static profit maximizer.[23] Marginal costs of voice call and text message usages are assumed to be zero, which may not be an unreasonable assumption if market demand does not exceed the maximum capacity the firm may provide internally (this turns out to be the case in our experiment results). Under this assumption the firm has to decide the pricing scheme for each service plan which includes access fees, free usages, and marginal prices for usages above, for both voice calls and text messages, in order to maximize the total expected revenue. We first compute the expected firm revenue, expected consumer surplus and expected usage under current prices. Then we try to find a "Pareto superior" three-part tariff pricing scheme which may increase the firm's revenue as well as the consumer surplus. After that, we will consider the optimal pricing

[23] We acknowledge that the firm's objective may be long-term profit maximization instead of just for current period. This may be important given that significant switching costs among consumers are found in our model estimation. However, to investigate optimal pricing under long-term profit maximization involves dynamic optimization technique which is very complicated in our current context. We leave this important issue for future research.

schemes which maximize the firm's revenue under the following scenarios: two- and three-part tariffs under service bundling, and two- and three-part tariffs under unbundling.

We study the expected total firm revenue assuming that consumers have perfectly learnt their own usage preferences when making the service plan choices. Expected revenue of the firm under bundling and three-part tariffs is defined as follows:

$$E\pi_{Three-part}^{bundle} = \sum_{t=1}^{T}\sum_{i=1}^{N}\sum_{j=1}^{J} E\left(\left(A_j + p_j^V \max\left(x_{ijt}^V - F_j^V, 0\right) + p_j^D \max\left(x_{ijt}^D - F_j^D, 0\right)\right)\cdot 1\{d_{it} = j\}\right)$$

where $1\{d_{it} = j\}$ denotes consumer i chooses plan j in period t. We simulate the usage preferences θ_{it}^V and θ_{it}^D for every consumer in every period based on our estimation results. These determine the consumer usages x_{ijt}^V and x_{ijt}^D conditional on plan j is chosen. We also simulate the service plan choice shocks ε_{ijt} and together with the simulated usages to compute the service plan choice d_{it}.[24] Under two-part tariffs, F_j^V and F_j^D are restricted to zero in the above equation and expected revenue of the firm is computed similarly.

We compute the expected consumer surplus following traditional definition. Under three-part tariffs, consumer i's expected surplus at time t is defined as

$$CS_{it} = \int \left[\begin{array}{l} \max\limits_{j\in J}\{\delta_j - A_j + \dfrac{\left(\theta_{it}^V\right)^2 \beta^V}{2}\cdot\left\{\theta_{it}^V > 0\right\} + \dfrac{\left(\theta_{it}^D\right)^2 \beta^D}{2}\cdot\left\{\theta_{it}^D > 0\right\} \\ \quad + \left[-\theta_{it}^V p_j^V + \dfrac{1}{2}\dfrac{1}{\beta^V}\left(p_j^V\right)^2 + p_j^V F_j^V\right]\left\{\theta_{it}^V > F_j^V + \dfrac{1}{\beta^V}\cdot p_j^V\right\} \\ \quad + \left[-\theta_{it}^D p_j^D + \dfrac{1}{2}\dfrac{1}{\beta^D}\left(p_j^D\right)^2 + p_j^D F_j^D\right]\left\{\theta_{it}^D > F_j^D + \dfrac{1}{\beta^D}\cdot p_j^D\right\};\forall j\} \end{array} \right] dF(\theta_{it}^V, \theta_{it}^D)$$

To compute this surplus we simulate the usage preferences θ_{it}^V and θ_{it}^D again based on our estimation results. For each draw of θ_{it}^V and θ_{it}^D we compute the consumer surplus conditional on the consumer service plan choice, allowing for the service

[24] Although we only compute expected revenue under the steady state, this simulation method allows for idiosyncratic usage and plan choice shocks in every period.

plan choice shocks ε_{ijt} as discussed above. Since the optimal price schemes imply that the firm introduces new service plans, we set all plan-specific parameters δ_j in the utility function to zero. Under two-part tariffs, F_j^V and F_j^D are restricted to zero in the above equation. The expected consumer surplus is computed similarly.[25] The expected social welfare is the sum of the firm's expected revenue and consumers' surplus[26].

Results for current prices are reported in Table 5 (the last two columns). The firm's total expected revenue is ¥288,800, where the total expected consumer surplus is ¥661,000, with an expected total market share 58.8 percent. Given that the firm only has two service bundles, it cannot fully extract the consumer surplus. Still, the fact that consumer surplus is much higher than firm's revenue perhaps indicates that current prices are sub-optimal for the firm's purpose of revenue maximization.

5.1 New "Pareto superior" plans

As the first exercise we search for another "Pareto superior" tariff plans under which the firm may obtain higher revenue but not decrease the total consumer surplus.[27] These new plans dominate the current plans from either the firm, policy maker or consumer perspective. We do find an example, which is reported in the right two columns in Table 5. Under the new scheme the firm significantly increase the access fee and free voice call usage for one plan. As a result, the firm revenue will increase by 4.5 percent while the consumer surplus will also increase by 0.3 percent. An interesting comparison is that while under the current pricing scheme the voice-centric plan (first plan) offers a higher voice call free usage and the data-centric plan (second plan) offers a higher text message free usage, under the new scheme the first plan offers both higher voice call and text message free usages than the second plan. As a result, the first plan will generate both higher voice call and

[25] The above expected profit and consumer surplus formula is specified for the bundling case, and the computation for the unbundling case is computed following similar procedure.
[26] This is a simplification from the general case that is a weighted sum of total consumer surplus and firm profits, where the weight represents the objective function of a social planner (e.g. Mirman and Sibley (1980)).
[27] We allow the case that some consumers might be worse off under this pricing scheme but overall consumers must be better off.

text message usages. This result implies that the firm would be better off by introducing one service plan targeting heavy users for both voice call and text message and another one targeting light users, which is very different from the current pricing scheme.

5.2 Optimal pricing schemes for the firm

Now we move on to the second set of experiments with the purpose of finding out what should be the optimal pricing schemes for the firm in order to maximize its revenue. We set up four scenarios for the firm's pricing practice: scenario I assumes three-part tariffs and two service bundles, scenario II assumes two-part tariffs and two service bundles. The final two scenarios are the cases of unbundling: scenario III assumes four plans under three-part tariffs, two plans solely providing voice calls and two plans solely providing text messages, and scenario IV assumes four similar plans, two for voice calls and two for text messages, under two-part tariffs. Consumers may choose their optimal combination of separate service plans, and are allowed to choose only one voice call or text message plan. Under each scenario we compute the expected firm revenue, consumer surplus, usages and market share as before. Results are reported in Table 6.

Comparing to the unbundling cases scenario III and scenario IV, by bundling services to extract consumer surplus the firm is able to generate higher revenue (from 7 to 8 percent) in scenarios I and II, while expected consumer surplus is lower in these scenarios. This result is consistent with findings in previous literature that bundling leads to higher firm profits even under the case of nonnegative correlated preferences (consumer preferences for voice calls and text messages are positively correlated in our estimation). As discussed in Sibley and Srinagesh (1997), bundling is superior to unbundling if the uniform ordering[28] of

[28] The condition that demand curves are uniformly ordering is that if $Q_{i+1,j}(P) > Q_{ij}(P)$ for all i, j, and P, where $Q_{ij}(P)$ is the demand function of consumer *i* for product *j*, this ordering of demand functions gives rise to the same ordering of utility functions that is independent of prices. Furthermore, if we can use a variable θ_{ij} to represent the demand function for *j*, i.e., $Q_{ij}(P) = Q(P, \theta_{ij})$, the uniform condition is equivalent to saying that for each θ_{ij} we can assign a

demand curves condition is weakly violated. We find that this condition is violated when preferences are positively correlated; hence, our finding is consistent with their theoretical result under two- and three-part tariffs. Since the bundling practice extracts more consumer surplus, this may drive those consumers who have very low preferences to switch to the outside option, as indicated by the lower expected market share in scenarios I and II. In the unbundling cases (scenarios III and IV) consumers are given the freedom to choose any combination of service plans. Consumers with high voice call preference but low text message preference may only choose the voice call plans.

Comparing scenario I to II and III to IV, we find the firm can generate higher revenue (from 1.2 to 2.5 percent) by using three-part tariffs. This is not surprising since under three-part tariffs the firm has an additional instrument (free usages). However, an interesting result is that scenarios I and II have an equivalent price structure for plan A. That is, when three-part tariffs are allowed the firm should only offer one three-part tariff plan and another is two-part tariff. Plan A offers lower marginal prices and a higher access fee without free usages, and plan B offers a lower access fee and free usages but higher marginal prices once above the amounts. It seems that the purpose of plan B may be to force a higher usage of both voice calls and text messages from its choosers. By doing so the firm will also increase its market share, as the expected market share in scenarios I and III are higher. As discussed in Jensen (2006), a simple two-part tariff pricing scheme is not optimal when competition exists since "the optimal nonlinear tariffs exhibits a convexity for low quantities". She demonstrates that the optimal pricing can be implemented if firms use a three-part tariff, and further shows some empirical examples from the telecommunication industry where firms offer three-part tariffs to low demand segments. Our empirical finding in this case seems to be consistent with her argument.

---

rank r_{ij}, so that $r_{ij}-1$ customers have lower values of θ_{ij} than consumer i and $N-r_{ij}$ consumers have higher values of θ_{ij}, and r_{ij} is the same for all j, where N is the total number of consumers in the market.

To better understand how the impacts of the pricing policies on different consumer segments we divide consumers into four segments according to their preferences: 1. high voice call and high text message preferences, 2. high voice call but low text message preferences, 3. low voice call but high text message preferences and, 4. low voice call and low text message preferences. The segmentation is based on our draws of θ_i^V and θ_i^D for every consumer in the simulation exercise. We use the medium criterion to split them into high vs. low types. The segment shares in the whole sample are 26.6%, 23.4%, 23.4%, 26.6%, respectively. We compute the service plan choices, consumer surplus usages for voice calls and text messages, and firm revenue of each segment for just one period. For illustration purpose we assume that there is no service plan choice error ε_{ij} and consumers have perfect information about their preferences. Consumers will choose the service plan generating the highest utility. Detailed segmentation results are reported in Table 7.

Market share and total firm revenue of segment 1 (high preferences for voice calls and text messages) are the highest across different scenarios. Segment 2 (high preference for voice calls) and segment 3 (high preference for text messages) are in the middle, and segment 4 (low preferences for both services) is the lowest. It is useful to first compare scenarios I and II. Though using three-part tariffs in scenario I attracts fewer consumers from segments 1 and 2, this is compensated by attracting more consumers from segments 3 and 4. The firm is also benefited from the fact that some consumers from segments 1 and 2 who would have chosen plan B under two-part tariffs shift to plan A under three-part tariffs, a plan with higher access fee and no free usages. These are the consumers with very high preference for voice calls (see the increase in total voice call usage for segments 1 and 2 under plan A). Consumer surplus across four consumer segments increases in scenario I (see the comparison of total surplus in Table 6); however, the surplus of segments 1 and especially 2 has become lower. It is the low voice call preference segments 3 and 4 gain a higher surplus under three-part tariffs. The firm's revenue from segment 2 is also lower under three-part tariffs, but it is compensated by the increase in revenue from segment 1 and especially from segments 3 and 4. Indeed under two-part tariffs in scenarios II and IV no consumers in segment 4 will choose to join in as users. This implies that in scenario I the firm uses the three-part tariff plan (plan B) to attract low preference consumers and encourage higher usage of both services through allowing free usages. The purpose of the two-part tariff plan (plan A) is to extract consumer surplus from those consumers in segments 1 and 2 with very high preference for voice calls. This pricing scheme comes at a cost that the firm will lose some consumers in segment 2; still, overall the firm will gain a larger market share across segments.

From Table 6 we find that the total consumer surplus is lower under the bundling cases (compare scenario I to III and II to IV). However, the impact is different for different consumer segments. Results from Table 7 show that though the surplus of consumers in segments 1 and 2 has declined, the surplus of consumers in segments 3 and 4 has indeed increased. Moreover, the firm is able to generate more revenue through bundling from segments 1, 3 and 4. Where do these increased revenues come from? A quick look at the total voice call and text message usage suggests that, comparing to the unbundling cases, the firm will be able to increase revenue through encouraging both usages. The decrease in firm revenue and total usage of voice call and text message in segment 2 is mainly due to the reduction in the number of choosers; however, the average usages of consumers within this segment who choose either service plan are indeed higher in the bundling case.

Since the expected usage of voice call and text message in the four scenarios are below the levels under the current prices, we do not expect any capacity constraint problem for the firm if the firm adopts the proposed optimal pricing schemes. Therefore, as we argued before, the assumption of zero marginal costs does not seem to be unreasonable.

Finally, Table 8 reports the elasticities corresponding to how plan choice probabilities, voice call and text message usage, as well as the firm revenue, change with respect to changes in access fee, voice call and text message marginal prices, and free usages for voice calls and text messages, under the optimal three-part tariff bundling case (scenario I in Table 6). In general the results are very different from the elasticities reported in Table 4. In particular, the revenue elasticities with respect to change in access fees, marginal prices and free usages are much closer to zero here, which are more consistent with the standard condition for revenue maximization. Furthermore, elasticities between the two service plans are also closer to each other.

5.3 A counter-factual experiment

Results from Table 6 show that the optimal three-part tariffs under bundling (scenario I) are that one plan (plan A) charges lower marginal prices and no free usages, while another plan (plan B) offers free usages for both voice calls and text messages but charges higher marginal prices for consumption above these allowances. Consequently heavy users for both voice calls and text messages will choose plan A while light users choose plan B. This is significantly different from the current pricing schemes, where the voice-centric plan offers higher voice call free usage and the data-centric plan offers higher text message free usage, and both charge the same marginal prices. We believe that the optimal pricing scheme computed above is mainly driven by the fact that the consumer preferences are positively correlated in our data. A consumer with a high voice call usage is also likely to have a high text message usage. To investigate how the optimal pricing policies change when consumer preferences are differently correlated, we conduct a counter-factual experiment by changing the correlation between individual voice demand intercept and message demand intercept from 0.057 to -0.1, and the correlation between idiosyncratic preference shocks for voice calls and text messages (l_{12}) from 0.174 to -0.174. Then we conduct the optimal pricing schemes for three- and two-part tariffs under bundling again. The results are summarized in Table 9. The structure of the optimal pricing schemes under this counter-factual case is vastly different from the optimal schemes in Table 6. Under both tariffs, we have one (voice centric) plan offering a high free voice call usage, low voice call marginal price, zero free text message usage, and high text message marginal price, and another (text centric) plan offering exactly the opposite pricing structure. This implies that when the consumer preferences are negatively correlated, the firm should offer different service bundles targeting high voice call users vs. high text message users. Under the three-part tariffs, the firm is able to charge a higher level of access fee and higher marginal prices to extract consumer surplus. Though free usages are offered, the total usage of voice calls and text messages are actually lower than the levels under two-part tariffs. As a result, total consumer surplus and the firm market share are lower under three-part tariffs.

We also break down into four consumer segments according to their preferences for voice calls and text messages as before, and compute the expected revenue, expected surplus, expected usage for voice calls and text messages and expected revenue of each segment. Results are reported in Table 10. The sizes of the four segments are 24.3%, 25.7%, 25.7% and 24.3%, respectively. Similar to Table 7, segment 1 is the segment with the highest revenue, segment 2 and segment 3 are in the middle, and segment 4 does not bring any revenue for the firm. There is a clear consumer plan choice pattern: under both tariffs segment 2 would choose the voice centric plan, and segment 3 would choose the data centric plan. Some consumers in segment 1 would choose the voice centric plan, and some choose the data centric plan, depending on the relative magnitude of their voice call preference against text message preference. In this case no consumers in segment 4 (low preferences type) would choose any service plan. It is interesting to note that both firm revenue and consumer surplus are larger for segment 2 (high preference for voice calls) under three-part tariffs, but lower for segment 3 (high preference for text messages). This result shows that the impacts on firm profit and consumer surplus could be different for different consumer segments.

Given that this pricing structure is more similar to the current pricing schemes, we conjecture that the firm may set its current prices based on the wrong belief that consumer preferences for voice calls and text messages are negatively correlated. Maybe the firm believes that voice call and text message are substitutes with each other. Our policy experiments illustrate the importance of understanding the underlying consumer preference structure in firm’s pricing decisions, which may be difficult without structurally modeling consumer service plan choice and usage decisions.

6 Conclusions

Product bundling and three-part tariff pricing are both popular market strategies. In this study, we use a dataset in the wireless industry to study the empirical impacts of these pricing strategies on firm profit and consumer surplus. We develop a structural demand model to study the underlying consumer preferences structure for product bundles under the three-part tariff pricing scheme. We find the consumer preference for voice calls positively correlated with that for text messages. We also model the impacts of switching costs and consumer learning on the dynamic service plan choice and switching behaviors, and find these variables play an important role in explaining the choice patterns observed in the data. Based on the demand estimates, we conduct policy experiments to explore the firm's optimal pricing schemes. We find product bundling and three-part tariff strategies both can be used to increase firm revenue. While bundling service helps to extract the consumer surplus, three-part tariffs in general helps to increase both firm revenue and consumer surplus. Interestingly, when consumer preferences for multiple products and services are positively correlated, the optimal pricing scheme is a combination of a two-part tariff targeting heavy users and a three-part tariff targeting light users. A counter-factual experiment shows that, when consumer preferences are negatively correlated, the optimal pricing scheme will be a combination of one plan targeting heavy voice call users and another plan targeting heavy text message users. These results offer important implications for the firm's pricing policies.

The main contribution of this paper is to fill a gap in the empirical literature by providing some empirical evidence for the impacts of three-part tariffs under product bundling on the firm profit and consumer surplus. There are some limitations to this research. First, though we incorporate consumers' learning and switching cost in our model, we do not model the consumer forward-looking behaviors. It may be important to study how a forward-looking consumer may behave differently from our model predictions. Second, constrained by the pricing variations in our data, we model the consumer utility function as additively separable for consuming voice calls and text messages. It will be interesting to allow for interactions of the two types of consumption in the utility function hence may generate a richer substitution or complementarity pattern. This objective can be achieved if we have sufficient price variations during the sample period of data. Finally, our policy experiments are based on the assumption that competitors do not respond to changes in the firm's pricing strategies. Hence our results are only partial equilibrium analyses. It is important, either empirically or theoretically, to study a full equilibrium model where firms compete by offering product bundles under different three-part tariff price structure to different consumer segments. Policy implications under such settings potentially can be different from our findings here. To address the above issues researchers have to collect richer datasets and to estimate under richer model specifications. Equilibrium conditions will be difficult to define and even non-tractable; however, we believe that it is important for the future research.

Figure 1: Price Scheme of Product Bundle under A Three-Part Tariff

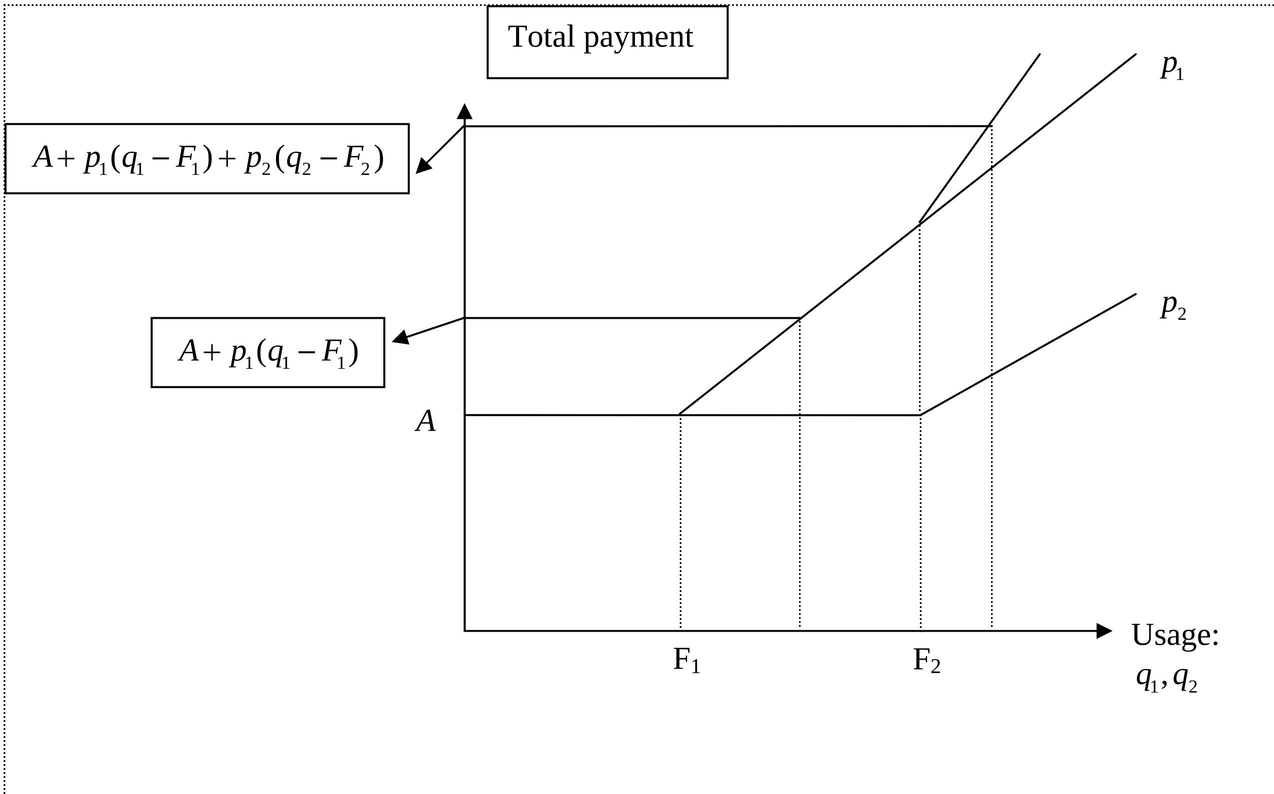

Figure 2: Market Share of Service Providers

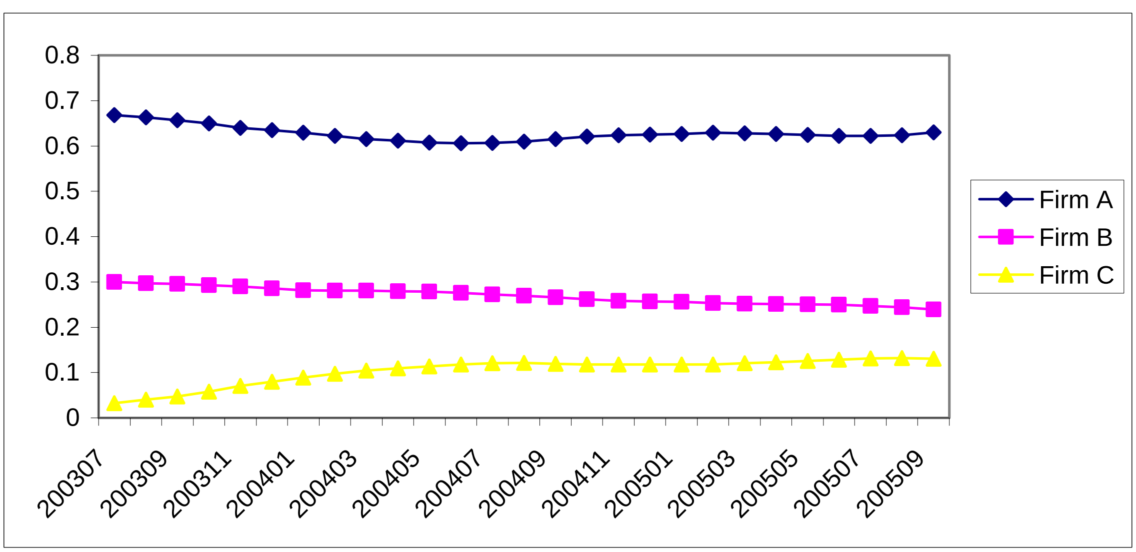

Figure 3: Users Development Pattern

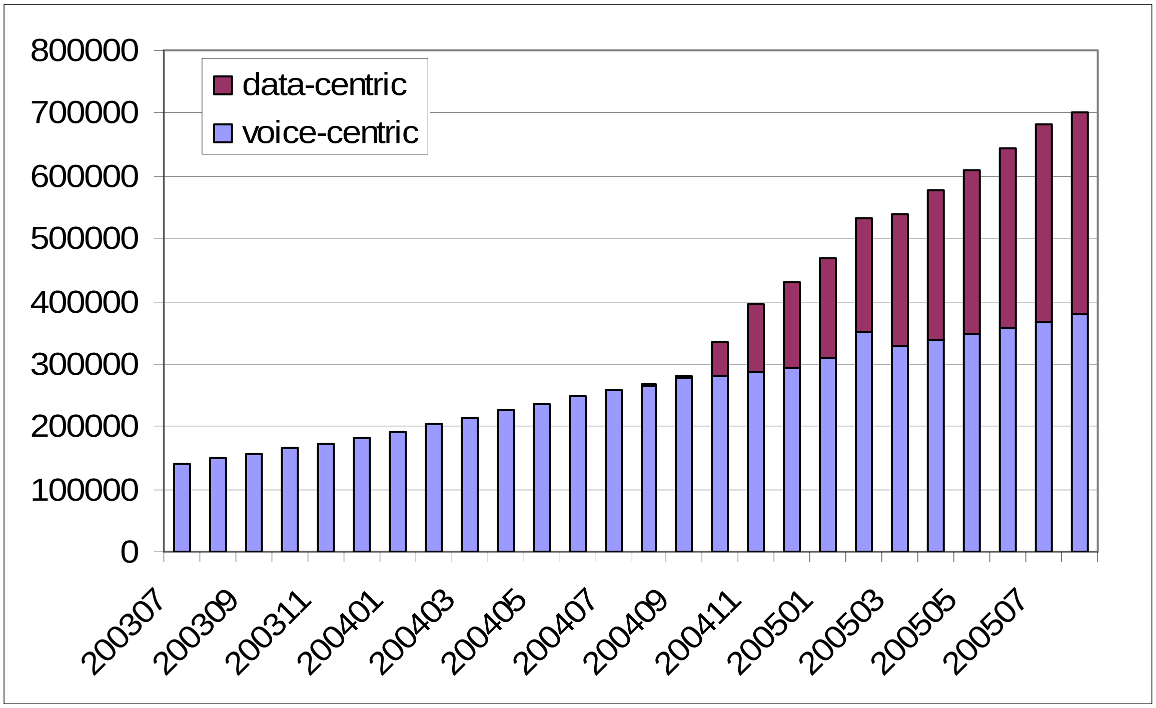

Figure 4: Gain vs. Loss of Switching from Voice-Centric to Data-Centric

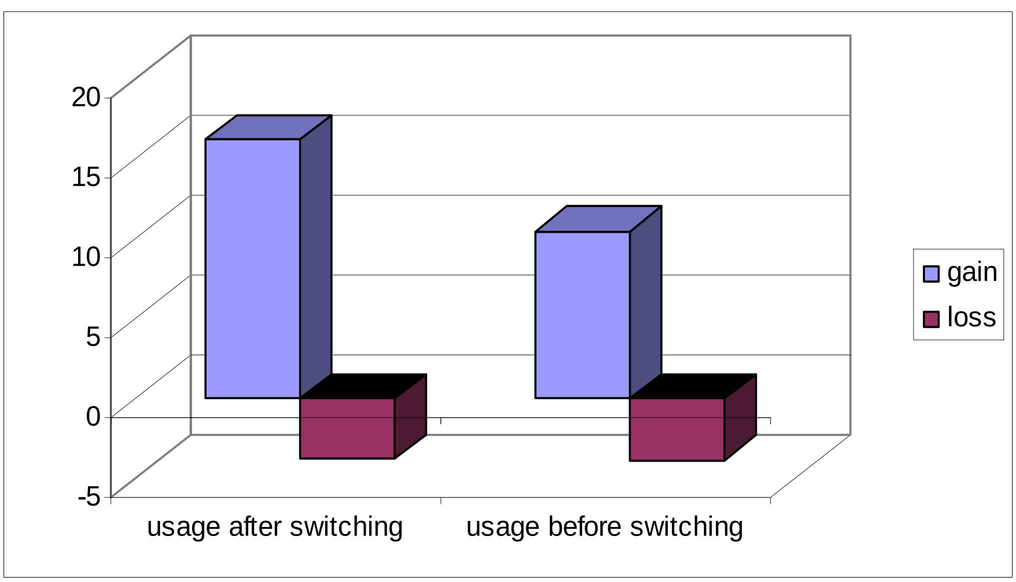

Table 1: Some Details of Pricing Schemes

	voice-centric	data-centric
access fee (¥/per month)	15(no roaming), 30(roaming)	20
on-net outgoing voice call price (¥/per minute)	0.2	0.2
on-net incoming voice call price (¥/per minute)	0	0
off-net outgoing voice call price (¥/per minute)	0.4	0.3
off-net incoming voice call price (¥/per minute)	0.2	0.2
on-net outgoing SMS text message price (¥/per message)	0.1	0.1
on-net incoming SMS text message price (¥/per message)	0	0
off-net outgoing SMS text message price (¥/per message)	0.15	0.15
off-net incoming SMS text message price (¥/per message)	0	0
free voice call minutes (value in ¥/per month)	¥16	¥12
free SMS messages (number)	0	300

Table 2: Some Usage Patterns of the Sample

	Average minutes of voice calls (standard deviation)	Average Number of text messages (standard deviation)
Whole sample (100%)	178 (232.3)	114.2 (191.9)
Stay with voice centric plan (40.9%)	170.8 (218.1)	28.3 (81.6)
Stay with data centric plan (30.9%)	184.5 (252)	217.9 (210.1)
Switchers from voice- to data-centric plan (5.6%)	212 (202.9)	164.2 (231.2)
Switchers from data- to voice-centric plan (3.1%)	189.9 (218.2)	113.3 (201.4)
Drop outs (19.5%)	168.9 (245.9)	129.9 (256.7)

Table 3: Estimation Results

	Model 1	Model 2	Model 3
Voice centric plan intercept	0.320 (0.022)	-1.900 (0.064)	-3.257 (0.101)
Data centric plan intercept	-0.380 (0.040)	-0.156 (0.032)	-1.620 (0.192)
Voice demand intercept	1.545 (0.01)	1.535 (0.032)	1.448 (0.046)
Message demand intercept	0.460 (0.01)	0.687 (0.031)	0.630 (0.050)
Standard deviation of voice demand intercept	0.383 (0.01)	0.157 (0.032)	0.38 (0.088)
Standard deviation of messages demand intercept	0.818 (0.008)	0.960 (0.031)	0.878 (0.402)
Correlation between voice demand Intercept and message demand intercept	0.029 (0.009)	0.160 (0.032)	0.057 (0.020)
Voice demand slope	-1.645 (0.006)	-1.574 (0.018)	-1.89 (0.012)
Message demand slope	-1.127 (0.011)	-1 (0.023)	-1.52 (0.036)
l_{11} *in unobserved preference covariance matrix*	2.214 (0.010)	2.245 (0.032)	2.233 (0.046)
l_{22} *in unobserved preference covariance matrix*	1.768 (0.004)	1.839 (0.030)	1.765 (0.043)
l_{12} *in unobserved preference covariance matrix*	0.169 (0.01)	0.236 (0.032)	0.174 (0.06)
Switching cost (within brands)		5.981 (0.158)	6.275 (0.168)
Standard deviation of switching cost (within brands)		0.794 (0.199)	0.98 (0.088)
Switching cost (across providers)		6.368 (0.117)	6.442 (0.121)
Log-Likelihood	**-19019**	**-12980**	**-12954**
Note: standard errors in parentheses *Note: the usage shock variance-covariance matrix is* $\Sigma_{\xi} = l'l$ *where* $l = \begin{bmatrix} l_{11} & l_{12} \\ 0 & l_{22} \end{bmatrix}$	$\begin{bmatrix} 4.903 & 0.374 \\ 0.374 & 3.155 \end{bmatrix}$	$\begin{bmatrix} 5.038 & 0.530 \\ 0.530 & 3.438 \end{bmatrix}$	$\begin{bmatrix} 4.990 & 0.389 \\ 0.389 & 3.145 \end{bmatrix}$

Table 4: Choice, Usages, and Revenue Elasticities under Current Pricing Scheme

	Voice-centric	Data-centric
Choice elasticity of access fee	-0.219	-0.134
Choice elasticity of marginal voice call price	-0.728	-0.524
Choice elasticity of marginal message price	-0.108	-0.009
Choice elasticity of free minutes	0.114	0.06
Choice elasticity of free messages	0.035	0.023
Voice usage elasticity of access fee	-0.079	-0.038
Message usage elasticity of access fee	-0.076	-0.041
Voice usage elasticity of marginal voice call price	-0.224	-0.121
Message usage elasticity of marginal voice call price	-0.118	-0.073
Voice usage elasticity of marginal text message price	-0.03	-0.001
Message usage elasticity of marginal text message price	-0.076	-0.005
Voice usage elasticity of free minutes	0.05	0.02
Message usage elasticity of free minutes	0.03	0.01
Voice usage elasticity of free messages	0.046	0.004
Message usage elasticity of free message	0.063	0.015
Revenue elasticity of access fee	0.186	0.101
Revenue elasticity of marginal voice call price	0.076	0.062
Revenue elasticity of marginal text messages price	0.069	-0.0001
Revenue elasticity of free minutes	-0.144	-0.06
Revenue elasticity of free messages	-0.114	-0.116

Table 5: Revenues, Consumer Surplus, Usages, and Firm Market Share under Current Pricing Scheme and A Better Pricing Scheme

Pricing structure	**A better pricing scheme**		**Current pricing scheme**	
Access fee (¥)	50	25	22.5	20
Voice calls marginal price (¥)	0.2	0.25	0.256	0.256
Text messages marginal price (¥)	0.1	0.1	0.1	0.1
Voice calls free usage (minutes)	250	52	63	47
Text messages free usage (number)	50	30	0	300
Expected total revenue (¥)	301,000		288,000	
Expected total consumer surplus (¥)	662,800		661,000	
Expected total voice calls usage (minutes)	915,900		873,900	
Expected total messages usage (number)	505,600		529,200	
Firm market share (%)	57.6%		58.8%	

Table 6 : Optimal Pricing Schemes -- Two-Part and Three-Part Tariffs, Bundling and Unbundling

	Bundling (Two bundling plans)				Unbundling (Two voice plans, Two message plans)							
Scenario	**I: three-part**		**II: two-part**		**III: three-part**				**IV: two-part**			
					voice		**message**		**voice**		**message**	
Service Plan	**A**	**B**	**A**	**B**	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**
Access fee (¥)	100	80	100	60	69.9	29.9	49.9	25	69.9	15	49.9	15
Voice calls marginal price (¥)	0.1	0.3	0.1	0.3	0.08	0.3	NA	NA	0.08	0.3	NA	NA
Messages marginal price (¥)	0.1	0.2	0.1	0.19	NA	NA	0.1	0.25	NA	NA	0.1	0.25
Voice calls free usage (minutes)	0	99	NA	NA	0	70	NA	NA	NA	NA	NA	NA
Messages free usage (number)	0	50	NA	NA	NA	NA	0	50	NA	NA	NA	NA
Average expected revenue per user (¥)	447	383	459	369	305	252	108	101	310	243	102	101
Average expected surplus per user (¥)	658	228	684	200	452	216	126	197	467	189	118	206
Average expected voice calls per user (minutes)	914	570	944	510	883	689	NA	NA	903	641	NA	NA
Average expected messages usage per user (number)	448	339	459	313	NA	NA	225	268	NA	NA	216	266
Expected total revenue (¥)	468,300		456,900		432,300				427,000			
Expected total surplus (¥)	500,300		498,300		558,600				553,000			
Expected total voice calls usage (minutes)	836,500		820,000		873,000				870,900			
Expected total messages usage (number)	442,200		435,400		278,500				268,700			
Total market share (%)	48.3%		47.4%		54.2%				54.0%			

Table 7: Revenues, Surplus, Usage by Segments Under Optimal Pricing Schemes -- Two-Part and Three-Part Tariffs, Bundling and Unbundling

		Bundling (Two bundling plans)				**Unbundling (Two voice plans, Two message plans)**							
Scenario		**I: three-part**		**II: two-part**		**III: three-part**				**IV: two-part**			
						voice		**message**		**voice**		**message**	
Service Plan		**A**	**B**	**A**	**B**	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**
Access fee (¥)		100	80	100	60	69.9	29.9	49.9	25	69.9	15	49.9	15
Voice calls marginal price (¥)		0.1	0.3	0.1	0.3	0.08	0.3	NA	NA	0.08	0.3	NA	NA
Messages marginal price (¥)		0.1	0.2	0.1	0.19	NA	NA	0.1	0.25	NA	NA	0.1	0.25
Voice calls free usage (minutes)		0	99	NA	NA	0	70	NA	NA	NA	NA	NA	NA
Messages free usage (number)		0	50	NA	NA	NA	NA	0	50	NA	NA	NA	NA
Total revenue (¥)	Segment 1	3,574	10,000	2,409	9,828	4,962	1,847	3,658	948	4,789	1,820	3,349	942
	Segment 2	1,077	1,931	0	6,772	5,407	0	3,755	0	5,063	0	3,357	0
	Segment 3	0	8,113	103	4,348	0	3,564	0	1,311	0	1,477	0	1,135
	Segment 4	0	2,792	0	0	0	0	0	0	0	0	0	0
Total surplus (¥)	Segment 1	3,699	1,996	2,986	3,051	1,354	1,412	2,993	1,597	1,242	1,412	2,496	1,565
	Segment 2	318	161	0	1,184	1,235	0	2,877	0	1,118	0	2,353	0
	Segment 3	0	2,499	130	1,516	0	932	0	1,415	0	932	0	1,331
	Segment 4	0	942	0	0	0	0	0	0	0	0	0	0
Total voice call usage (minutes)	Segment 1	6,667	1,249	4,708	15,306	9,498	4,819	NA	NA	9,390	4,717	NA	NA
	Segment 2	2,352	1,879	0	11,586	11,915	0	NA	NA	11,431	0	NA	NA
	Segment 3	0	8,824	67.2	5,433	0	3,564	NA	NA	0	3,224	NA	NA
	Segment 4	0	3,571	0	0	0	0	NA	NA	0	0	NA	NA
Total text message usage (number)	Segment 1	3,009	8,053	2,176	8,728	NA	NA	5,567	2,276	NA	NA	4,997	2,269
	Segment 2	737	2,032	0	5,974	NA	NA	6,550	0	NA	NA	5,574	0
	Segment 3	0	6,106	0	3,684	NA	NA	0	2,747	NA	NA	0	2,500
	Segment 4	0	2,139	0	0	NA	NA	0	0	NA	NA	0	0
Segment share (%)	Segment 1	5.3	14.5	3.5	16.8	10.5	4.8	11.0	6.0	9.7	4.8	10.1	4.4
	Segment 2	1.6	3	0	11.1	11.0	0	11.0	0	9.9	0	9.9	0
	Segment 3	0	12.9	0.1	8.1	0	6.0	0	0	0	6.0	0	6.0
	Segment 4	0	4.1	0	0	0	0	0	6.0	0	0	0	0

Table 8: Choice, Usages, and Revenue Elasticities under Optimal Three-Part Tariffs

	Plan A	Plan B
Choice elasticity of access fee	-0.73	-0.693
Choice elasticity of marginal voice call price	-0.13	-0.393
Choice elasticity of marginal text message price	-0.15	-0.20
Choice elasticity of free minutes	0.006	0.009
Choice elasticity of free messages	0.008	0.009
Voice usage elasticity of access fee	-0.471	-0.127
Message usage elasticity of access fee	-0.455	-0.143
Voice usage elasticity of marginal voice call price	-0.135	-0.124
Message usage elasticity of marginal voice call price	-0.08	-0.07
Voice usage elasticity of marginal text message price	-0.05	-0.03
Message usage elasticity of marginal text message price	-0.15	-0.12
Voice usage elasticity of free minutes	0.005	0.002
Message usage elasticity of free minutes	0.003	0.001
Voice usage elasticity of free messages	0.004	0.007
Message usage elasticity of free message	0.15	0.12
Revenue elasticity of access fee	-0.06	-0.07
Revenue elasticity of marginal voice call price	-0.003	-0.007
Revenue elasticity of marginal text messages price	-0.03	-0.05
Revenue elasticity of free minutes	-0.005	-0.062
Revenue elasticity of free messages	-0.004	-0.052

Table 9: Optimal Pricing Schemes -- A Counter-Factual Pricing Experiment

Pricing structure	**Three-part tariffs**		**Two-part tariffs**	
Access fee (¥)	99.9	99.9	89	79.9
Voice calls marginal price (¥)	0.1	0.15	0.05	0.13
Messages marginal price (¥)	0.15	0.1	0.15	0.08
Voice calls free usage (minutes)	260	0	NA	NA
Messages free usage (number)	0	250	NA	NA
Average expected revenue per user (¥)	397	381	379	386
Average expected surplus per user (¥)	536	398	450	492
Average expected voice calls per user (minutes)	895	644	782	767
Average expected messages usage per user (number)	353	437	338	447
Expected total revenue (¥)	439,200		431,300	
Expected total consumer surplus (¥)	527,00		531,200	
Expected total voice calls usage (minutes)	868,300		873,300	
Expected total messages usage (number)	445,500		442,800	
Firm market share (%)	48.9%		49.8%	

Table 10: Revenues, Surplus, Usage by Segments Under Optimal Pricing Schemes

-- A Counter-Factual Pricing Experiment

Pricing structure		**Three-part tariffs**		**Two-part tariffs**	
Access fee (¥)		99.9	99.9	89	79.9
Voice calls marginal price (¥)		0.1	0.15	0.05	0.13
Messages marginal price (¥)		0.15	0.1	0.15	0.08
Voice calls free usage (minutes)		260	0	NA	NA
Messages free usage (number)		0	250	NA	NA
Total revenue (¥)	Segment 1	7,545	2,530	4,260	5,660
	Segment 2	4,481	0	4,290	0
	Segment 3	0	5,250	0	5,420
	Segment 4	0	0	0	0
Total surplus (¥)	Segment 1	2,320	2,120	1,530	3,310
	Segment 2	795	0	783	0
	Segment 3	0	1,964	0	2,320
	Segment 4	0	0	0	0
Total voice call usage (minutes)	Segment 1	11,920	3,400	7,160	9,020
	Segment 2	6,540	0	7,080	0
	Segment 3	0	5,445	0	6,780
	Segment 4	0	0	0	0
Total text message usage (number)	Segment 1	6,980	2,240	4,060	6,120
	Segment 2	3,345	0	3,590	0
	Segment 3	0	4,570	0	4,710
	Segment 4	0	0	0	0
Segment share (%)	Segment 1	10.8	3.5	3.7	11.7
	Segment 2	6.1	0	6.4	0
	Segment 3	0	7.8	0	9.2
	Segment 4	0	0	0	0

Reference

Adams, W.J., J.L. Yellen (1976), "Commodity bundling and the burden of monopoly," Quarterly Journal of Economics, 90, 475-498.

Ackerberg, D. (2003), "Advertising, Learning and Consumer Choice in Experience Good Markets: An Empirical Examination," International Economic Review, 44, 1007-1040.

Armstrong, M. (1996), "Multiproduct Non-Linear Pricing," Econometrica, 64(1), 51-75.

Armstrong, M. (1999), "Price Discrimination by a Many-Product Firm," Review of Economic Studies, 66, 151-168.

Bakos, Y. and Brynjolfsson, E. (1999), "Bundling Information Goods: Pricing, Profits and Efficiency," Management Science, 45, 1613-1630.

Chan, Tat and B. Hamilton (2006), ""Learning, Private Information and the Economic Evaluation of Randomized Experiments," Forthcoming in Journal of Political Economy

Chu,C.H., P., Leslie and A. Sorensen (2006), "Incomplex Alternatives to Mixed Bundling," Working paper, Stanford University.

Clay Karen, Goettler Ronald, and Eric Wolff (2003), "Consumer Learning about Experience Goods: Evidence from an Online Grocer," Working paper, Carnegie Mellon University.

Coscelli, A. and M. Shum (2004), "An Empirical Model of Learning and Patient Spillovers in New Drug Entry," 122, Journal of Econometrics, 213-246.

Crawford, G. and M. Shum (2002), "Uncertainty and Learning in Pharmaceutical Demand," Mimeo, University of Toronto.

Crawford, Gregory S. (2005), "The Discriminatory Incentive to Bundle in the Cable Television Industry," Working paper.

Degroot, Morris H. (1970), "Optimal Statistical Decisions," New York: McGraw-Hill.

Dubin, J.A., and D. McFadden (1984), "An Econometric Analysis of Residential Electric Appliance Holdings and Consumption," Econometrica, 52, 345-362.

Economides, N., K.Seim and V.B.Viard (2004), "Quantifying the Benefits of Entry into Local Telephone Service," Working paper, Stanford University.

Erdem, T. and P. Keane (1996), "Decision-Making under Uncertainty: Capturing Dynamic Brand Choice Processes in Turbulent Consumer Goods Markets," Marketing Science, 15, 1-20.

Grubb, M. (2005), "Screening Overconfident Consumers," Working paper.

Hanemann,W.M. (1984), "Discrete/Continuous Models of Consumer Demand," Econometrica, 52, 541-561.

Hausman,Jerry A. (1985), "The Econometrics of Non-Linear Budget Sets," Econometrica, 53, 1255-1282.

Iyengar, Raghuram (2004), "A Structural Demand Analysis for Wireless Services under Nonlinear Pricing Schemes," Working paper, Columbia University.

Jensen, Sissel (2006), "Implementation of Competitive Nonlinear Pricing: Tariffs with Inclusive Consumption," Forthcoming in Review of Economic Design.

Klemperer, (1995), "Competition When Consumers have Switching Costs: An Overview with Applications to Industrial Organization, Macroeconomics, and International Trade," Review of Economic Studies, 62, 515-539.

Kotler, P. (1997). Marketing Management: Analysis, Planning, Implementation and Control (9^{th} ed.). New Jersey: Prentice Hall.

Lambrecht, A., K.Seim and B.Skiera (2005), "Does Uncertainty Matter? Consumer Behavior under Three-Part Tariffs," Working paper.

Lieberman, M.B. and D.B., Montgomery, D.B. (1988). “First-Mover Advantages.” Strategic Management Journal, 9, 41-58.

McAfee, R.P., J.McMillan and M.D.Whinston (1989), “Multi-product monopoly, commodity bundling, correlation of values,” Quarterly Journal of Economics, 114, 371-384.

Mirman, L.J and D.S.Sibley (1980), “Optimal Nonlinear Prices for Multi-product Monopolies,” Bell Journal of Economics, 11, 659-670.

Mitchell, Bridger M. and Vogelsang Ingo (1991), Telecommunications Pricing: Theory and Practice. Cambridge University Press.

Moshkin, N. and R. Shachar (2002), “The Asymmetric Information Model of State Dependence,” Marketing Science, 21, 435-454.

Narayanan Sridhar, Pradeep K. Chintagunta and Eugenio J. Miravete (2005). “The Role of Self Selection and Usage Uncertainty in the Demand for Local Telephone Service,” Working Paper.

Epling, N. (2002). “Price Discrimination amid Heterogeneous Switching Costs: A Competitive Tactic of the Telephony Resale Fringe,” Working Paper, Yale University.

Porter, M.E. (1980). Competitive Strategy: Techniques for Analyzing industries and Competitors. New York: Free Press.

Porter, M.E. (1985). Competitive Advantage: Creating and Sustaining Superior Performance. New York: Free Press.

Reisinger, Markus (2004). “The Effects of Product Bundling in Duopoly,” Working paper.

Salinger, M.A (1995), “A Graphical Analysis of Bundling”, Journal of Business, 68(1), 85-98.

Schmalensee, R.L. (1984). “Gaussian demand and commodity bundling,” Journal of Business, 57, S211-S230.

Sibley, David S. and Padmanabhan Srinagesh (1997). "Multiproduct Nonlinear Pricing with Multiple Taste Characteristics," Rand Journal of Economics, 28 (4), 684-707.

Train, Kenneth E., M. Ben-Akiva, and T. Atherton (1989), "Consumption Patterns and Self-Selecting Tariffs," Review of Economics and Statistics, 71(1), 62-73.

Wilson, Robert B. (1992). Nonlinear Pricing. Oxford University Press.