The Impact of Asymmetric Regulation on Product Bundling: The Case of Fixed Broadband and Mobile Communications in Japan[1]

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Abstract

Product bundling may benefit or harm consumers depending on the correlation between consumer willingness to pay for the bundled goods and the levels of market dominance of firms. We develop a structural demand model that allows for correlated consumer's willingness to pay and flexible complementarities/substitutabilities. We estimate this model using data from three surveys conducted by the Japan Ministry of Internal Affairs and Communications. The estimation results show that (i) fixed broadband and mobile communications are complements for the Japanese telecommunication incumbent but ambiguous for competitors; and (ii) only the services provided by the incumbent exhibit high demand elasticities. Therefore, a decrease in the price set by the incumbent increases the market demand without any loss of competition. To assess the effect of asymmetric regulation on product bundling by the incumbent, we conduct a counterfactual analysis of a two-stage game where firms choose whether to bundle or not fixed-broadband and mobile communications at stage one and set prices at stage two. The subgame perfect Nash equilibrium of the two-stage game with/without asymmetric regulation shows that bundling is the dominant strategy for the incumbent and it increases consumer surplus by 8.9% and the equilibrium diffusion rates of fixed broadband and mobile communications from 92.5% to 93.9% and 95.8% to 96.9%, respectively. However, banning bundling by all firms increases consumer welfare and social welfare. Promoting regional broadband operators to enter mobile market is alternative way to draw efficiency gain from product bundling. MVNO's We also find that pure bundling, as a tool for leverage, is not a subgame perfect Nash equilibrium.

Keywords: Fixed-to-mobile substitution, Bundles, Leverage, Discrete-Choice Model
JEL Classification: L4, L96, D43

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[1] This analysis employed data from the Statistical Surveys for the Competition Review in the Telecommunications Business Field in Fiscal Year 2013 and the Communications Usage Trend Survey 2012, provided by the Japan Ministry of Internal Affairs and Communications.

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1. Introduction

Most prominent motivations of product bundling are price discrimination and entry deterrence[1]. Firms choose mixed bundling as a competition tools In oligopoly markets, price discrimination tends to intensify price competition and increase consumer surplus (Anderson and Leruth, 1993; Economides, 1993; Liao and Tauman, 2002; Thanassoulis, 2007)[2]. However, the incumbent can use product bundling to deter entry (Whinston, 1990; Nalebuff, 2004; Peitz, 2008; Hurkens et al., 2013)

Regarding bundling as an entry barrier, the Japan Ministry of Internal Affairs and Communications (MIC) has prohibited the incumbent to bundle fixed communication and mobile communication services that include calls and data. This asymmetric regulation results in asymmetric behavior between firms - the incumbent provides its goods separately while competitors offer mixed-bundling. In 2012, a competitor introduced a bundle of fixed broadband and mobile communications. Given that the bundled product is differentiated from the separate goods, the market share of this competitor remarkably increased after introducing the bundle.

The aim of our research is to determine whether maintaining the asymmetric regulation is beneficial to consumers or not. By the end of fiscal year (FY) 2013, the share of the incumbent NTT reached 71% in the fixed broadband market and 43.8% in the mobile communications market (MIC, 2014.) The shares of the largest competitor were 19.0% and 28.5%, respectively. When the business stealing effect of bundling is weak, allowing the incumbent to bundle exacerbates price competition and increases consumer surplus. However, if the business stealing effect of bundling is strong, competitors might exit from the market and consumer surplus may decline.

The effect of bundling depends on the correlation between the goods bundled (Stigler, 1963; Adams and Yellen, 1976; McAfee et al, 1989; Fang and Norman, 2006; Reisinger, 2006.) To assess this effect, we develop a structural demand model that allows for correlated consumer's willingness to pay (WTP) for goods and flexible complementarities/substitutabilities.

The estimation results show that (i) fixed broadband and mobile communications are complements for NTT but ambiguous for competitors; and (ii) the demand elasticity is high only for NTT services. This result implies that a bundle discount by NTT would increase market demand without significant loss of competition.

We also conduct a counterfactual analysis of a two-stage game where firms choose

[1] Following McAfee et al (1989), we use “bundling” to represent mixed bundling. When we focus on pure-bundling, we surely write “pure-bundling”.

[2] Thanassoulis (2007) shows what conditions make mixed bundling works for or against the consumer interest.

whether to bundle or not to bundle at stage one and choose prices of their goods at stage two. The subgame perfect Nash equilibrium of this game shows that bundling is the dominant strategy for the incumbent and that asymmetric regulation affects the market equilibrium. It follows that, under asymmetric regulation, the incumbent cannot choose bundling to increase its profit. Under the counterfactual situation that allows incumbent to bundle, we find that all firms choose to bundle and that consumer surplus increase by 8.9%. However, social surplus decreases 6.5% because of following two facts. The first welfare loss depends on the fact that incumbent and one competitor increases fixed broadband prices to avoid cannibalization between bundle and fixed broadband. The second welfare loss depends on the fact that firm provides bundle goods to consumers who has lower willingness to pay for components than marginal costs.

The profit loss by competitors is not large enough to force them to exit the market.

We also assess the use of pure bundling instead of mixed bundling as a tool for leverage. We argue that it is profitable for the incumbent to use pure bundling instead of mixed bundling when competitors do not bundle. However, the best response by a competitor to pure bundling by the incumbent is mixed-bundling. We conclude that allowing the incumbent to bundle fixed broadband and mobile communications is beneficial to consumers and increases social surplus in the Japanese telecommunications market.

The remainder of the paper is organized as follows. In Section 2, we review the literature related to our study. Section 3 gives an overview of the Japanese telecommunications market. Section 4 introduces the demand model and econometric implementation. Section 5 presents the estimation results and counterfactual analysis. Finally, Section 6 concludes.

2. Literature Review

Product bundling regulation is a controversial issue. Economists have shown that the price discrimination effect of product bundling tends to exacerbate price competition and increase consumer surplus (Anderson and Leruth, 1993; Economides, 1993; Liao and Tauman, 2002; Thanassoulis, 2007). However, the incumbent can use product bundling to deter entry (Whinston, 1990; Nalebuff, 2004; Peitz, 2008). Hurkens et al (2013) formalized the level of market dominance for which bundling has an entry-deterrent effect. The evaluation of such level of dominance is therefore an empirical issue.

To assess the effect of product bundling in oligopoly markets, the econometrician should tackle with the demand correlation of goods and the firm strategy. The effect of product bundling on firm profits or consumer surplus depends on demand correlation. Under monopoly, negative correlation between goods bundled increase the profit of product bundling (Stigler, 1963; Adams and Yellen, 1976; McAfee et al., 1989; Fang and Norman, 2006). In oligopoly markets, Reisinger (2006) shows that bundling increases consumer surplus when WTP for goods bundled are negatively correlated, because bundling exacerbates price competition. However, Chen (1997) found that product bundling not only works as a tool for price discrimination, but also for product differentiation. The equilibrium choice of product bundling has many equilibria that are sensitive to model assumptions.

The literature on demand estimation of differentiated products allows the econometrician to estimate a model that provides flexible complementarities/substitutabilities. We follow Gentzkow (2007) to assess whether the goods bundled are complements or substitutes. We also add the correlation of WTP for the goods bundled by employing a mixed logit model with a control function (Petrin and Train, 2010).

Our paper contributes to three fields of empirical literature. The first contribution is to the empirical research on the effect of bundling on price and welfare. Gentzkow (2007) assesses the complementarities or substitutabilities between print and online newspapers. Crawford (2008), and Crawford and Yurukoglu (2012) estimate the effect of bundling substitutes in the cable television industry. Shiller and Waldfogel (2011) compares firm profit and consumer surplus under various pricing schemes on music. Ho et al. (2012) finds that full-line forcing contracts between movie distributors and video retailers increase consumer and producer surplus. Luo (2012) shows that mixed bundling is beneficial to both the firm and the consumer under monopoly. Kuroda (2014) shows that the bundle of public broadcast channels increases consumer surplus under break-even regulation. Burnett (2014) shows that service bundling reduces consumer switching. We empirically assess the impact of both demand correlation and goods complementarities on the market effect of product bundling and find equilibrium prices.

The second contribution is to the empirical literature on the communication industry that includes fixed and mobile communications. Vogelsang (2010) reviewed a growing body of literature on substitution between fixed and mobile phones. Grzybowski and Verboven (2014) found fixed broadband technologies generate strong complementarities between fixed and mobile access. We assess firm specific complementarities between fixed broadband and mobile communication services.

The third contribution is to the emerging empirical literature on the firm's incentives to bundle. Fox and Lazzati (2015) provides the identification strategy by using potential games. Macieira et al (2014) investigated the firms' incentives to provide or not to provide Triple-Play under oligopoly market. To the best of our knowledge this is the first paper to assess the effect of asymmetric regulation on the incentives to bundle products in the telecommunications markets. Furthermore, we analyze the equilibrium choice of product bundling and assess the incentive to use pure bundling instead of mixed bundling as a tool for leverage.

3. The Japanese Telecommunications Market

In this Section, we briefly review the Japanese competition policy and structure of the telecommunications market.

In 1985, the telecommunications incumbent NTT group was privatized and the telecommunications market liberalized. Due to public concern about leveraging the monopoly power in the local phone market, the Japanese government introduced a number of asymmetric regulations; in particular, access charges for fixed line use and mobile termination rates. It is prohibited for NTT to provide TV services. Up to February, 2015, NTT was not allowed bundling fixed services and mobile services. Supported by such pro-competition regulation, many firms have entered the market and consolidated their position over the last decades. By the end of 2014, the Japanese market of telecommunication services is dominated by three large national groups.

The largest national group is the NTT group. The NTT group includes two regional telecommunications operators that provide fixed telephony and broadband services in each of their local markets and one national operator of mobile services. As of the end of FY2013, its market shares of fixed broadband and mobile communications are 54.5% and 40.2%, respectively[3]. The regional operators announced in 2014 the wholesale provision of their Fiber to the Home (FTTH) services to any firm, including their affiliate mobile operator. The MIC approved such intragroup wholesale provision of FTTH services on February, 2015 thus enabling them to set bundle pricing.

One of the two national competitors of the NTT group is the KDDI group. The KDDI group originated from the former national monopoly firm for international calls. It merged in 2000 with mobile operator IDO which is partially financed by Toyota and two regional electricity monopoly firms in the Tokyo and Chubu areas[4]. In the mid

[3] The market share data is taken from MIC (2014).
[4] Tokyo is the capital of Japan. The headquarters of Toyota Company in Toyota city are located in the Chubu area.

2000s, KDDI also acquired FTTH facilities from those electricity firms in their operating areas. In the early 2010s, KDDI acquired the largest CATV group. In 2012, it introduced bundle-pricing on fixed broadband and mobile communications. Households using fixed broadband services provided by KDDI obtain a monthly fee reduction of ¥1480 (approximately $12 using the exchange rate in May, 2014) for each smartphone line subscribed. Compared to the ¥5460 flat rate fee for data services, the discount rate is 27%. The MIC (2013) reports a rapid increase in the number of KDDI subscribers of fixed broadband after the introduction of the bundle-discount. By the end of FY2013, its market shares in the fixed broadband and mobile communications markets are 19.0% and 28.4%, respectively.

The other national competitor of the NTT group is the SoftBank group. It is also one of most successful venture firms in the Japanese IT industry. It entered the telecommunications market by providing Asymmetric Digital Subscriber Line (ADSL) services in 2001, and the mobile communications market by acquiring Vodafone's mobile operator in 2006. Later, SoftBank acquired other firms that include a DSL operator and mobile operators. Because the Softbank group provides mainly ADSL services for fixed broadband, the ongoing migration to FTTH services has been reducing its share in the fixed broadband market (Ida and Sakahira, 2008). By the end of FY2013, its share in the fixed broadband market is only 8.1%. However, SoftBank's mobile market share is 31.4%. The firm introduced bundle-pricing on fixed broadband and mobile communications after KDDI introduced it.

There are also a number of regional fixed broadband operators in Japan. K-opticom, the largest regional operator in the fixed broadband market, belongs to the regional electricity monopoly of The Kansai Electric Power group. K-opticom has invested in FTTH facilities since the market was liberalized. The firm entered the telecommunications market at the end of the 1980s and the fixed-broadband market in 2001. It has a 4.1% share in the national fixed broadband market. However, its operating region share is equal to that of NTT. Furthermore, K-opticom and other regional electricity monopolies provide bundle discount with mobile communications services by KDDI. In addition, regional electricity monopoly in Kyusyu area had provided bundle discount with mobile communications services by SoftBank [5]. Furthermore, many regional CATV operators exist. CATV providers were regional monopolies until 1993. A large number of regional operators in large cities merged with national CATV operators and were acquired by KDDI. Various CATV regional

[5] SoftBank grope has their professional baseball team based in Fukuoka that is the largest city in Kyusyu area.

operators also provide bundle discount with KDDI. We combine those firms that provide bundle discount with KDDI into the KDDI group.

4. Demand Model and Econometric Implementation

4.1 Demand Model

In this section, we propose an econometric method to estimate a structural demand model that allows for flexible complementarities/substitutabilities and demand correlation between goods. We adopt the model of Gentzkow (2007) to estimate flexible complementarities/substitutabilities. In addition, to evaluate the effect of bundling, we adopt the model of Macieira et al. (2014) to estimate the choice of alternatives. We also control for the endogeneity of expenditure of alternatives by a control function approach by Petrin and Train (2010).

Suppose consumer $i=1,...,N$ chooses among alternatives j that may combine goods, which include fixed broadband provided by firm $f=1,...,F$, mobile communications provided by firm $m=1,...M$, or possibly provided by different firms. Denote $f=0$ if consumer i does not use fixed broadband and $m=0$ if consumer i does not use mobile communications. The number of alternatives is $(F+1)\times(M+1)$.

The utility that consumer i obtains from alternatives j is as follows:

$$U_{ij}=\Gamma_{ij}+\delta_{if}+\delta_{im}-\alpha y_{ij}+\varepsilon_{ij}$$

where y_{ij} is the endogenous expenditure when consumer i chooses alternative j, δ_{if} and δ_{im} are, respectively, the utility from fixed broadband provided by firm f and mobile communications provided by firm m, Γ_{ij} is the difference between the base utility of bundle j and the sum of the utility of separate goods included alternative j [6], ε_{ij} is the utility that is unobservable for the econometrician but observed by the consumer when making the decision.

Because of unobserved attributes, such as quality of networks, ε_{ij} could be

[6] Because the data lack sufficient choice variation to estimate firm independent Γ_i and firm specific complementarity Γ_{ij}, we assume that complementarities work only if consumer i chooses fixed broadband and mobile communications provided by the same firm. This assumption meets our observations in Table 1.

correlated with y_{ij}. We control for the endogeneity of y_{ij} by using the control function approach. The expenditure for alternative j is determined by consumer characteristics x_i, exogenous variables z_j, and a single unobserved factor u_{ij} that is independent of x_i and z_j:

$$y_{ij} = h(x_i, z_j, \gamma_j) + u_{ij}$$

where γ_j denotes the parameters of this function.

We adopt the simplest approximation that assumes that ε_{ij} is linear in u_{ij}

$$\varepsilon_{ij} = \lambda u_{ij} + \tilde{\varepsilon}_{ij}$$

where λ is a scalar parameter of the control function, and $\tilde{\varepsilon}_{ij}$ is i.i.d extreme value over j.

The choice probability of consumer i for alternative j is equal to

$$P_{ij} = \int \Pr(U_{ij} > U_{ik} \forall j \neq k \mid u_{ij}) d\tilde{\varepsilon}_i$$

where $\tilde{\varepsilon}_i$ is a vector of $\tilde{\varepsilon}_{ij}$. We adopt the mixed logit model that assumes that δ_{if}, δ_{im}, and Γ_{ij} are normally distributed and correlated to each other. Therefore, the choice probability is:

$$P_{ij} = \int \frac{\exp(\Gamma_{ij} + \delta_{if} + \delta_{im} - \alpha y_{ij})}{1 + \sum_j \Gamma_{ij} + \delta_{if} + \delta_{im} - \alpha y_{ij}} f(\Gamma_{ij}, \delta_{if}, \delta_{im}) d\Gamma_{ij} d\delta_{if} d\delta_{im}$$

where $f(\Gamma_{ij}, \delta_{if}, \delta_{im})$ is the joint normal distribution $N(\theta, \Sigma)$. The integral is approximated through simulation. We draw $f(\Gamma_{ij}, \delta_{if}, \delta_{im})$ by using 300 Halton draws that perform better than random draws (Train, 2009).

The model is estimated in two steps. First, we regress y_{ij} on x_i and z_j, and calculate $\hat{y}_{ij}$ and $\hat{u}_{ij}$, that are the expected values of y_{ij} and u_{ij}, respectively. We use expenditure of alternative j in other region for z_j. We use $\hat{y}_{ik}(k \neq j)$ as the expenditure for alternative k that consumer i does not choose. Second, we estimate the mixed logit model using y_{ij} as the expenditure for the observed choice, $\hat{y}_{ij}$ for the unobserved choice, and $\hat{u}_{ij}$ for the control function. Following Petrin and Train (2010), we calculate standard errors by bootstrap methods from 100 bootstrap samples.

4.2 Econometric Implementation

We employ data from three different surveys. We use two individual choice surveys conducted by the MIC in February, 2014. The first survey consists of 2,010 individual broadband internet users in Japan. The respondents are collected by a two-stage stratified random sampling that obtains sample individuals proportional to the shares of fixed broadband technologies (FTTH, CATV, and ADSL) by regions reported by firms to the MIC. The second survey consists of 500 individual mobile communications users who are not fixed-broadband users in Japan. Mobile communications users include mobile telephony and mobile data users. Both surveys have been conducted by means of online surveys[7]. The sum of the two surveys corresponds to the ratio of fixed broadband internet users and mobile communications users found in the Communications Usage Trend Survey 2012 that was conducted in accordance with the Statistics Act for official statistics in Japan. Those two internet surveys are designed for the Competition Review in the Telecommunications Business Field performed by the MIC. We obtain data on the choice of fixed broadband and mobile communications, monthly expenditure of those services and socio-demographic characteristics (sex and age) of consumers.

The above mentioned surveys exclude any individual who does not use fixed broadband or mobile communications. Therefore, we draw those individuals from the Communications Usage Trend Survey 2012. This survey was sent by post to 40,592 households in proportion to region and city size. The MIC obtained 20,418 valid responses in February, 2013. This survey asked respondents about individual and

[7] According to the Communications Usage Trend Survey 2012, 71.1% of individuals use mobile phone and 64.9% of individuals use mobile internet. These statistics show that the sampling bias generated by the internet survey is not large.

household usage of communication services and their socio-demographic characteristics but not about their choice of firms and expenditures. The survey shows that the ratio of people who does not use fixed broadband internet or mobile phone is 46.4%. Therefore, we draw 1,230 respondents who do not use internet or mobile phone from this survey and combine them to the respondents of the survey of the Competition Review. Finally, we obtain 3,740 observations that include 2,000 broadband users, 2,298 mobile phone users and 1,239 non-users that are approximately proportional to the Communications Usage Trend Survey 2012[8]. Combining those surveys enable us to assess the counterfactual choice of fixed broadband and mobile communications by households that do not use fixed broadband nor mobile communications.

Table 1 presents the choice of alternatives in the sample and the hypothetical share that assumes that the consumer's choice is independent between fixed broadband and mobile communications ($P(f,m) = P(f) * P(m)$). Table 1 shows that the mobile communications usage rate among fixed broadband users is 89.9% and among non-broadband users is 28.4%. The data also show that consumers tend to choose the same firm's fixed broadband and mobile communications. Particularly, fixed broadband users of KDDI tend to choose mobile communications provided by KDDI rather than NTT. Such consumer choice pattern reflects the fact that KDDI provides bundle services and that consumers are loyal to a chosen brand. In contrast, the alternatives that combine different firm's services are not always higher than the hypothetical share under the independent-choice hypothesis. This fact implies that the complementarity between fixed broadband and mobile communications works only between the same firm's services.

Table 2 describes the statistics of expenditure, age and sex over alternatives. The expenditure for bundles of fixed broadband and mobile communications is lower than the sum of expenditure for separate services, because consumers can reduce their expenditure by using, for instance, fixed broadband to make a call or using a smartphone or tablet to access the internet through Wi-Fi. The bundle discount for (KDDI, KDDI) does not have a strong effect on average expenditure[9]. Consumers who do not use fixed broadband tend to be younger than consumers who use both fixed broadband and mobile communications. Consumers who choose (None, None) tend to

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[8] 9 respondents in the second survey use "Other operator's mobile phone services." There are local WiMAX operators in 40 cities, out of a total of 1,742 cities. Because McFadden (1984) recommends including at least 30 observations of every alternative, it is difficult to treat those operators as independent choices. Therefore, we combine those respondents into non-mobile communication users.

[9] The Communications Usage Trend Survey 2012 reports the diffusion rate of smartphone is 49.5%. Not all KDDI users are eligible for bundle discount.

be the oldest. Therefore, the utility of goods differs over consumer characteristics. We control for this fact by using age and sex as mean shift variables for goods utilities δ_{if} and δ_{im} , and flexible complementarities/substitutabilities Γ_{ij} .

5. Estimation Results and Counterfactual Analysis

5.1 Estimation Results

We present the estimates of δ_{if} , δ_{im} , Γ_{ij} , α and λ in Table 3[10]. Parameter distributions and correlations improve the model fitness measured by McFadden's pseudo R. The sign of Γ_{ij} differs between firms. NTT and SoftBank have negative Γ_j but that of KDDI is positive. However, in contrast with Gentzkow (2007), the correlation between goods brings further complexity to assess whether goods are complements or substitutes.

Table 4 indicates the correlation between service utilities. Fixed broadband provided by NTT is negatively correlated with all other goods. On the other hand, all other goods are positively correlated with each other. It depends the fact that NTT grope is prohibited to do joint marketing activities between regional fixed operators and mobile operator [11] . This negative correlation between fixed broadband and mobile communications of NTT implies that the demand for the bundle of NTT is large relative to that of other firms.

Table 5 displays price elasticity of separate goods. Cross-price elasticity of fixed broadband to other fixed broadband is positive. Similarly, cross-price elasticity of mobile communications to other mobile communications is positive. However, fixed broadband and mobile communications by NTT are complements. In contrast with NTT, those of KDDI and SoftBank are ambiguous.

Table 6 shows expenditure elasticity of bundle goods. As expected, the elasticity of

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[10] Parameters of θ_i and $\Sigma = (LL^*)$ are shown in the Appendix.

[11] NTT grope's corporate color is vivid blue. However, NTT's mobile operator only use red as its corporate color. See http://www.ntt.co.jp/. In contrast with NTT, KDDI grope use their mobile operator's brand "au" not only its mobile services but also its FTTH services. It also uses orange as united corporate color. See http://www.au.kddi.com. In line with KDDI, SoftBank grope also use silver as their united corporate color. See http://softbank.jp/. The fact that SoftBank grope has their baseball teal Fukuoka SoftBank Hawks explain strong demand correlations between their fixed broadband and mobile communications.

bundle goods is the highest for NTT in mixed logit with correlation. Comparing the bundle elasticities estimated by the mixed logit without correlation with the mixed logit with correlation, the demand correlation significantly strengthens the effect of bundle pricing. However, a large part of customers comes from outside of the market. The total amount of business stealing effects is weak. Consequently, bundling by NTT promotes broadband diffusion without significant reduction of its competitors profits.

5.2 Counterfactual Analysis of Asymmetric Regulation of Product Bundling

We use the estimates fitted by the mixed logit with correlation to perform our counterfactual analysis. To avoid a multiple equilibria problem, we do not estimate marginal cost from the specific equilibrium. Alternatively, we use the access charge as a proxy for marginal cost. We use the access charge as the marginal cost for both fixed broadband and mobile communications. The mobile communications access charge is the sum of access charges for voice and data. We use the voice termination charge as voice cost. We use the Mobile Virtual Network Operator (MVNO) data interconnection charge as data cost. The voice termination and MVNO interconnection charges are regulated by the MIC to ensure that they reflect a reasonable cost, which is approximately average cost pricing. This regulatory framework gives us the opportunity to calculate the marginal cost per user. We present the cost per consumer in Table 7. We assume that the marginal cost is constant and that there are no economies of scope.

We employ the following two-stage game:

Stage 1: The three national groups j simultaneously choose whether or not to bundle, $b_j \in \{0,1\}$.

Stage 2: Firms choose optimal price for services. If a national group chooses to bundle, it sets the price of fixed broadband, mobile communications, and the bundle of those services $[p_j^F, p_j^M, p_j^B]$, respectively. If a national group chooses not to bundle, it sets $[p_j^F, p_j^M]$. In other words, firm j sets $p_j^B = p_j^F + p_j^M$ when it chooses not to bundle. Other firms set $[p_j^F]$.

The profit of firm j is

$$\Pi_j = p_j^B s_{jj} + p_j^F \sum_{k \neq j} s_{jk} + p_j^M \sum_{k \neq j} s_{kj}$$

where s_{fm} is the market share defined by the choices of firm f for fixed broadband and firm m for mobile communications. Population in the market is normalized to one. The first-order condition for a Bertrand-Nash equilibrium in the second stage is

$$\frac{\partial \Pi_j}{\partial p_j^B}=0, \frac{\partial \Pi_j}{\partial p_j^F}=0, \frac{\partial \Pi_j}{\partial p_j^M}=0 \Leftrightarrow$$

$$s_{jj}+(p_j^B-mc_j^F-mc_j^M)\frac{\partial s_{jj}}{\partial p_j^B}+(p_j^F-mc_j^F)\frac{\partial}{\partial p_j^B}\left(\sum_{m\neq j} s_{jm}\right)+(p_j^M-mc_j^M)\frac{\partial}{\partial p_j^B}\left(\sum_{f\neq j} s_{fj}\right)=0$$

$$\sum_m s_{jm}+(p_j^B-mc_j^F-mc_j^M)\frac{\partial s_{jj}}{\partial p_j^F}+(p_j^F-mc_j^F)\frac{\partial}{\partial p_j^F}\left(\sum_{m\neq j} s_{jm}\right)+(p_j^M-mc_j^M)\frac{\partial}{\partial p_j^F}\left(\sum_{f\neq j} s_{fj}\right)=0$$

$$\sum_f s_{fj}+(p_j^B-mc_j^F-mc_j^M)\frac{\partial s_{jj}}{\partial p_j^M}+(p_j^F-mc_j^F)\frac{\partial}{\partial p_j^M}\left(\sum_{m\neq j} s_{jm}\right)+(p_j^M-mc_j^M)\frac{\partial}{\partial p_j^M}\left(\sum_{f\neq j} s_{fj}\right)=0$$

When firm j chooses not to bundle, the first constraint on p_j^B does not bind. The local-fixed broadband firms are bound by second constraints only.

We numerically calculate the above first-order conditions over the estimated individual parameters in the sample that are provided by a Bayesian Procedure. We minimize the square of the left-hand side of the above equations by using the Generalized Reduced Gradient method. The stopping rule is set as 10^{-5}.

Table 8 shows the equilibrium prices, firm profits and consumer surplus in the second stage equilibria. Firms' first stage choice is combined to vector $B=(b_{NTT}, b_{KDDI}, b_{SoftBank})$. The subgame perfect Nash equilibrium with asymmetric regulation is $B=(0,1,0)$. Bundle is the dominant strategy for KDDI but not for SoftBank.

Table 8 also indicates that the subgame perfect Nash equilibrium without asymmetric regulation is $B=(1,1,1)$. Bundling is the dominant strategy for NTT and KDDI. Comparing expenditure for alternative (NTT, NTT) and sum of separate goods for NTT, NTT discount their bundle products for ¥890. Comparing profits by firm, profit decreases by ¥18(0.3%) for NTT, ¥610(24.7%) for KDDI and ¥47 (4.1%) for SoftBank. Because product bundling intensifies price competition, national operators' profits are decreases. In contrast with national operators, the profit for other fixed operators increases $73(17.2%). It depends the fact that NTT and SoftBank increases fixed broadband prices to avoid cannibalization between bundle and fixed broadband. It gives beneficial externality for regional broadband operators who does not provides mobile services. Relaxing asymmetric regulation also increases consumer surplus ¥416. Firm provides bundle goods to consumers who has lower willingness to pay than marginal costs, this facts reduces social surplus ¥180.

Table 9 presents the equilibrium market share for $B=(0,1,0)$ and $B=(1,1,1)$. Given that the diffusion rates of fixed broadband and mobile communications increase from 92.5% to 93.9% and from 95.8% to 96.9%, respectively.

We also consider the equilibrium when the government regulates product bundling for all firms. Comparing equilibria between $B=(0,0,0)$ and $B=(0,1,0)$, consumer surplus increases by 15.6%. The sum of profits decreases by 7.4%. The social surplus of $B=(0,0,0)$ is higher than that $B=(0,1,1)$ by 0.3%. However, comparing equilibria between $B=(1,1,1)$ and $B=(0,1,0)$, consumer surplus and social surplus of $B=(0,1,0)$ is higher that of $B=(1,1,1)$. Because there exist regional operator who does not provides mobile services, they are able to increases their prices under $B=(1,1,1)$. In contrast with $B=(1,1,1)$, the effect of product differentiation by bundle could not work between fixed firms in $B=(0,0,0)$. It intensifies competition between firms. It is possible for regional operators to provide mobile communication services as MVNO and bundle it . This fact makes possible to draw the competition intensifying effect of bundling.

5.3 The use of pure bundling

The theory of leverage predicts that the incumbent has an incentive to use pure bundling instead of mixed bundling as a tool for leverage. Table 10 shows the equilibrium profits when the incumbent chooses pure bundling. Pure bundling of the incumbent is dominated by mixed-bundling except if competitors choose separate selling. Chen (1997) found that product bundling works as a tool for product differentiation. However, competitors increase their profit by using mixed bundling. Since this is not a subgame perfect equilibrium, we find that pure bundling is not a tool for leverage for the Japanese telecommunication incumbent.

6. Conclusion

Allowing the incumbent to bundle goods for which it has dominance is a controversial issue. Economic theory provides guidelines for efficiency-increasing bundling and anti-competitive bundling. However, the market outcome derived by product bundling strongly depends on the demand function for the bundled goods.

Therefore, only an empirical approach can be taken to assess the effect of prohibition for product bundling.

We estimate a structural demand model for fixed broadband and mobile communications with flexible complementarities/substitutabilities. We also estimate the demand correlations between bundled services. Our estimation results show that (i) fixed broadband and mobile communications are complements for incumbent but ambiguous for competitors, and (ii) the demand elasticities of services are high only for incombant. This implies that a decrease in price by NTT increases the market demand without any loss of competition.

Using estimated demand parameters, we assess the effect of asymmetric regulation on product bundling. For this purpose, we perform a counterfactual analysis of a two-stage game and show that bundling is the dominant strategy for the incumbent. The profit for the incumbent decreases by 0.3% and that for competitors are ¥24.7% for KDDI and 4.1% for SoftBank. However, because of combination of national grope's cannibalization and strategic complementarity, the regional fixed broadband operator's profit increases 17.2%. All competitors are still able to earn enough profit to remain in the market. Consequently, incumbent product bundling increases consumer welfare. Diffusion rates of fixed broadband and mobile communications increase by 1.41% points and 1.06% poits, respectively. This analysis offers empirical evidence in favor of the recent decision of the Japanese MIC to allow incumbent product bundling to benefit consumers. We also find that pure bundling is not a tool for leverage in the Japanese telecommunications market.

We also find that banning bundling force firms to compete without differentiation by product bundling. It is the most efficient equilibrium but firm does not choose. However, it is also possible to lead regional fixed broadband operator to enter the mobile communications market as MVNO. It could intensify competition than our findings.

Our findings are likely to contribute to shaping the competition policy in the telecommunications market as well as the diffusion policy of fixed broadband and mobile communications. We must emphasize that product bundling in the Japanese telecommunications market has a positive effect for consumers because the market dominance of the incumbent has become small enough to enable other firms to compete in the market. Combination of Bundling and competition is the key feature of efficiency gain. Choi and Stefanadis (2001) shows that bundling could reduce consumer and total economic welfare if bundling causes any dynamics with investment. Future research consists in assessing the regional effect of product bundling using detailed consumer demand panel data.

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Table 1 Market Share

Choice Share

Fixed Broadband	Mobile communications NTT	KDDI	SoftBank	None	Sum
NTT	10.91%	4.84%	5.75%	2.67%	24.17%
KDDI	2.81%	6.52%	2.33%	1.02%	12.67%
SoftBank	2.22%	1.36%	2.46%	0.70%	6.74%
Other	4.57%	1.98%	2.57%	1.04%	10.16%
None	3.10%	5.59%	4.44%	33.13%	46.26%
Sum	23.61%	20.29%	17.54%	38.56%	100.00%

Hypothetical share under independent assumption

Fixed Broadband	Mobile communications NTT	KDDI	SoftBank	None	Sum
NTT	5.71%	4.91%	4.24%	9.32%	24.17%
KDDI	2.99%	2.57%	2.22%	4.89%	12.67%
SoftBank	1.59%	1.37%	1.18%	2.60%	6.74%
Other	2.40%	2.06%	1.78%	3.92%	10.16%
None	10.92%	9.39%	8.11%	17.83%	46.26%
Sum	23.61%	20.29%	17.54%	38.56%	100.00%

Table 2 Expenditure and characteristics over alternatives

Alternative (Fixed, Mobile)		Number of observations	Expenditure (thousand yen)	S.D of expenditure	Difference of expenditure from sum of sepalate alternatives	Age	Rate of Men
1	(NTT, NTT)	408	8.761	4.808	-0.3	46.7	63.5%
2	(NTT, KDDI)	181	9.112	5.603	-0.1	46.9	70.2%
3	(NTT, SoftBank)	215	8.520	3.839	-0.7	46.7	65.1%
4	(NTT, None)	100	4.443	3.206		51.0	70.0%
5	(KDDI, NTT)	105	9.780	6.426	-0.6	47.3	67.6%
6	(KDDI, KDDI)	244	9.016	4.420	-1.5	47.3	68.0%
7	(KDDI, SoftBank)	87	9.738	4.244	-0.8	49.6	67.8%
8	(KDDI, None)	38	5.758	2.797		49.9	73.7%
9	(SoftBank, NTT)	83	6.579	3.234	-1.2	45.7	63.9%
10	(SoftBank, KDDI)	51	5.985	3.029	-1.9	48.0	60.8%
11	(SoftBank, SoftBank)	92	7.807	3.698	-0.2	48.0	66.3%
12	(SoftBank, None)	26	3.137	1.462		47.3	73.1%
13	(Other, NTT)	171	8.176	3.626	-0.2	47.3	68.4%
14	(Other, KDDI)	74	8.018	4.330	-0.4	47.1	73.0%
15	(Other, SoftBank)	96	8.429	3.867	-0.1	47.4	64.6%
16	(Other, None)	39	3.679	1.286		49.8	69.2%
17	(None, NTT)	116	4.668	3.244		39.8	65.5%
18	(None, KDDI)	209	4.720	2.465		41.6	67.0%
19	(None, SoftBank)	166	4.821	2.638		43.2	66.9%
20	(None, None)	1239	0.000	0.000		62.6	39.7%
Total	(ALL, ALL)	3740	5.004	5.092		51.7	57.8%

Table 3 Estimation results

		MNL		Mixed Logit		Mixed Logit with Correlation	
Number of Observations		3740		3740		3740	
Number of Parameters		12		42		87	
Log-likelihood at convergence		−9847.212		−8575.95629		−8364.92478	
McFadden R		0.1211		0.2346		0.2534	
Adjusted McFdden R		0.1200		0.2341		0.2525	
		Estimates	Std. Err	Estimates	Std. Err	Estimates	Std. Err
δ_f	NTT	−0.6458 ***	0.0135	15.2725 ***	2.3104	23.4373 **	10.5133
	KDDI	−1.4725 ***	0.0314	−136.4310 ***	15.2284	−11.8075	14.4678
	SoftBank	−1.9923 ***	0.1472	−23.5690	87.37	16.9470	15.5345
	Other	−1.2115 ***	0.0498	−90.5020 ***	25.9571	7.1900	9.6989
δ_m	NTT	−0.4996 ***	0.0114	19.9558 ***	4.34788	44.4027 ***	8.8849
	KDDI	−0.5292 ***	0.0262	11.8004 ***	2.27581	52.6545 ***	9.0467
	SoftBank	−0.4408 ***	0.0171	17.9757 ***	2.88788	43.5472 ***	7.3491
Γ	NTT	1.3046 ***	0.0596	−0.1044	6.17561	−23.6629 *	13.3886
	KDDI	1.6238 ***	0.0595	20.3188 ***	6.1504	13.4539	17.5637
	SoftBank	0.9674 ***	0.1966	−36.7924	73.8453	−18.6142	56.7806
α		−0.0861 ***	0.0096	−3.4218 ***	0.06637	−4.8782 ***	0.1274
λ		0.0692 ***	0.0337	3.4880 ***	0.2948	4.8699 ***	0.2331
Standard deviations of Parameters							
δ_f	NTT			0.3535	2.523	8.33565	10.08179
	KDDI			190.154 ***	9.679	68.3508 ***	9.95051
	SoftBank			36.0101	47.5794	31.5431 ***	10.69081
	Other			105.711 ***	16.0128	38.7961 ***	9.64624
δ_m	NTT			24.6216 ***	4.35232	54.6814 ***	9.76583
	KDDI			46.64 ***	2.43558	66.9291 ***	8.65307
	SoftBank			0.52343	4.20851	30.8452 ***	9.19806
Γ	NTT			0.30287	7.50843	58.9305 ***	13.80601
	KDDI			71.2091 ***	11.9735	113.766 ***	14.90701
	SoftBank			42.8449	30.6831	57.9294 **	23.31524

* = significant at the 10% level; **= significant at the 5% level; and *** = significant at the 1% level.

Table 4 Correlation matrix of random parameters

Correlation		δ_f				δ_m			Γ		
		NTT	KDDI	SB	Other	NTT	KDDI	SB	NTT	KDDI	SB
δ_f	NTT	1	−0.71351	−0.80418	−0.69542	−0.44984	−0.60446	−0.8434	0.55999	0.71011	0.6739
	KDDI	−0.71351	1	0.68232	0.3421	0.08608	0.01679	0.68616	−0.18522	−0.07969	−0.80002
	SoftBank	−0.80418	0.68232	1	0.13492	0.09453	0.45579	0.61027	−0.19906	−0.62248	−0.40772
	Other	−0.69542	0.3421	0.13492	1	0.66904	0.49635	0.68047	−0.72355	−0.45917	−0.6102
δ_m	NTT	−0.44984	0.08608	0.09453	0.66904	1	0.77749	0.71646	−0.9917	−0.53037	−0.19765
	KDDI	−0.60446	0.01679	0.45579	0.49635	0.77749	1	0.58857	−0.8057	−0.90488	0.04502
	SoftBank	−0.8434	0.68616	0.61027	0.68047	0.71646	0.58857	1	−0.78383	−0.49851	−0.69634
Γ	NTT	0.55999	−0.18522	−0.19906	−0.72355	−0.9917	−0.8057	−0.78383	1	0.58954	0.27897
	KDDI	0.71011	−0.07969	−0.62248	−0.45917	−0.53037	−0.90488	−0.49851	0.58954	1	0.05147
	SoftBank	0.6739	−0.80002	−0.40772	−0.6102	−0.19765	0.04502	−0.69634	0.27897	0.05147	1

Table 5 Price elasticities of separate goods

MNL

1% Expenditure Change		NTT	KDDI	SoftBank	Other	None	NTT	KDDI	SoftBank	None
	NTT	−0.515	0.165	0.165	0.165	0.165	−0.207	0.049	0.019	0.093
Fixed	KDDI	0.085	−0.598	0.085	0.085	0.085	0.041	−0.167	0.022	0.053
Broadband	SoftBank	0.032	0.032	−0.446	0.032	0.032	0.010	0.008	−0.061	0.018
	Other	0.054	0.054	0.054	−0.476	0.054	0.001	−0.009	−0.028	0.017
Mobile	NTT	−0.212	0.068	0.073	0.029	0.075	−0.489	0.151	0.151	0.151
communicat	KDDI	0.028	−0.285	0.051	0.000	0.054	0.125	−0.493	0.125	0.125
ions	SoftBank	−0.001	0.015	−0.140	−0.037	0.025	0.104	0.104	−0.487	0.104

Mixed Logit

1% Expenditure Change		NTT	KDDI	SoftBank	Other	None	NTT	KDDI	SoftBank	None
	NTT	−3.645	0.000	0.006	0.000	1.577	0.216	0.000	0.446	−0.468
Fixed	KDDI	0.000	0.000	0.000	0.000	0.000	−0.179	−0.005	−0.327	0.360
Broadband	SoftBank	0.002	0.000	−0.069	0.000	0.008	−0.070	0.000	−0.006	0.054
	Other	0.000	0.000	0.000	0.000	0.000	−0.275	0.000	−0.093	0.259
Mobile	NTT	0.228	0.000	0.000	0.000	−0.099	−2.367	0.004	0.651	1.197
communicat	KDDI	−0.148	0.000	−0.007	0.000	0.065	0.004	−0.019	0.003	0.007
ions	SoftBank	0.523	0.000	−0.018	0.000	−0.224	0.713	0.004	−5.638	3.493

Mixed Logit with correlations

1% Expenditure Change		NTT	KDDI	SoftBank	Other	None	NTT	KDDI	SoftBank	None
	NTT	−6.931	0.002	0.456	0.045	2.328	−3.624	−0.001	0.001	2.010
Fixed	KDDI	0.001	−0.056	0.101	0.000	0.000	0.000	−0.002	−0.002	0.002
Broadband	SoftBank	0.089	0.035	−0.808	0.037	0.057	0.011	0.001	0.000	−0.006
	Other	0.014	0.000	0.066	−0.256	0.036	0.007	−0.001	−0.008	0.000
Mobile	NTT	−4.155	−0.016	0.104	0.008	1.425	−3.816	0.011	0.001	2.110
communicat	KDDI	−0.602	0.000	0.111	−0.029	0.199	0.011	−0.017	0.001	0.002
ions	SoftBank	−0.729	0.000	0.000	−0.014	0.255	0.001	0.001	−0.018	0.007

Table 6 Price elasticities of bundle goods

MNL

1% Bundle Discount	NTT	KDDI	SoftBank	Other	None	NTT	KDDI	SoftBank	None
NTT	−0.2746%	0.0882%	0.0879%	0.0880%	0.0876%	−0.2836%	0.0881%	0.0881%	0.0876%
KDDI	0.0514%	−0.3586%	0.0511%	0.0512%	0.0508%	0.0513%	−0.2007%	0.0513%	0.0508%
SoftBank	0.0167%	0.0168%	−0.2272%	0.0166%	0.0162%	0.0167%	0.0167%	−0.0771%	0.0161%

Mixed Logit

1% Bundle Discount	NTT	KDDI	SoftBank	Other	None	NTT	KDDI	SoftBank	None
NTT	−1.2798%	0.0000%	0.0031%	0.0000%	0.4773%	−0.0009%	0.0002%	0.0006%	0.0001%
KDDI	0.0000%	−0.0006%	0.0008%	0.0000%	0.0000%	0.0133%	−0.0306%	0.0034%	0.0076%
SoftBank	0.0014%	0.0000%	−0.0347%	0.0000%	0.0039%	0.0102%	0.0005%	−0.0123%	0.0028%

Mixed Logit with correlations

1% Bundle Discount	NTT	KDDI	SoftBank	Other	None	NTT	KDDI	SoftBank	None
NTT	−1.5141%	0.0000%	0.0000%	1.1435%	0.4722%	0.0000%	0.0000%	0.0000%	0.0000%
KDDI	0.0000%	−0.5142%	0.8083%	0.1700%	0.0001%	0.1425%	−0.2009%	0.0463%	0.0000%
SoftBank	0.0001%	0.0412%	−0.2710%	0.1269%	0.0001%	0.0038%	0.0108%	−0.0366%	0.0086%

Table 7 Marginal Cost of goods

		Monthly cost per customer (thousand yen)
Fixed Broadband	NTT	3.006
	KDDI	3.108
	SB	1.631
	Other	2.983
Mobile communications	NTT	1.432
	KDDI	2.708
	SB	3.257

*The cost for fixed broadband is the weighted average of FTTH access charge (¥3108) and ADSL(¥1371). The weights are based on MIC surveys. Since there is no CATV access charge, we assume that the cost of CATV is the same as FTTH.

**The cost for mobile communications is the sum of voice and data services costs. The cost of voice services are calculated as 2 * termination charge of firm j * Minutes of Use of firm j. The termination charge per 3 minutes for NTT was ¥10.26, for KDDI was ¥12.78, and for SotBank was ¥12.06 in 2013. Average minutes of usage per subscriber is 73min in 2013. The cost of data services are calculated using the data access charge of 10Mbps per month. The access charge for NTT was ¥1,230,000, KDDI was ¥2,750,000, and SoftBank was ¥3,520,000 in 2013. The MIC reports that average smartphone user's data usage in 2013 was 4.2GB per month. Therefore, we assume that the total amount of data transferable in 30 days is the same for consumer data usage if all consumers used smartphones.

Table 8 Bertrand-Nash equilibriums in second stages

	B	(1,1,1)	(0,1,1)	(1,1,0)	(0,1,0)	(1,0,1)	(0,0,1)	(1,0,0)	(0,0,0)
Prices of Fixed Broadband	NTT	4.166	3.866	4.428	3.886	4.176	3.898	4.143	3.808
	KDDI	8.704	10.04	18.67	10.50	4.697	5.331	3.782	3.151
	SoftBank	2.759	2.789	2.345	2.716	2.829	2.947	3.003	2.933
	Other	4.888	4.894	3.638	4.777	5.205	4.738	5.242	5.241
Prices of Mobile communicatio	NTT	7.146	4.223	19.93	4.201	8.411	4.178	9.411	4.276
	KDDI	6.789	6.768	12.11	10.68	6.571	5.880	7.734	8.475
	SoftBank	5.981	6.045	15.99	5.994	5.988	6.094	5.702	6.050
Prices of Bundle	NTT	8.041		8.028		8.025		8.022	
	KDDI	10.51	10.52	9.67	10.61				
	SoftBank	2.588	2.467			3.674	2.727		
Firms' Profits	NTT	**5.142**	4.978	**5.209**	5.160	**5.409**	5.094	**5.681**	5.257
	KDDI	**1.863**	**1.917**	**3.432**	**2.473**	1.766	1.701	1.850	1.777
	SoftBank	**1.097**	1.033	0.156	**1.144**	1.138	1.027	**1.205**	**1.135**
	Other	0.496	0.458	0.248	0.423	0.457	0.397	0.446	0.350
Sum of Profits		8.598	8.386	9.045	9.200	8.770	8.220	9.182	8.519
Consumer Surplus		5.111	5.408	2.993	4.695	5.091	5.748	4.748	5.423
Social Surplus		13.71	13.79	12.04	13.89	13.86	13.97	13.93	13.94

* Underline = best responses in first stage

Table 9 Market share in equilibria

B(1,1,1)		Mobile communication				
		NTT	KDDI	SoftBank	None	Sum
Fixed Broadband	NTT	47.62%	6.98%	7.63%	0.26%	62.48%
	KDDI	1.51%	5.98%	1.81%	0.73%	10.04%
	SoftBank	2.17%	0.99%	7.24%	0.82%	11.22%
	Other	4.58%	2.94%	2.63%	0.00%	10.14%
	None	1.46%	2.07%	1.30%	1.29%	6.12%
	Sum	57.33%	18.96%	20.61%	3.10%	100.00%

B(0,1,0)		Mobile communication				
		NTT	KDDI	SoftBank	None	Sum
Fixed Broadband	NTT	47.03%	8.49%	8.73%	0.70%	64.94%
	KDDI	4.43%	5.89%	2.01%	0.94%	13.27%
	SoftBank	2.93%	0.22%	2.27%	0.92%	6.34%
	Other	5.38%	0.11%	2.43%	0.00%	7.92%
	None	3.36%	1.78%	0.77%	1.61%	7.53%
	Sum	63.14%	16.50%	16.21%	4.16%	100.00%

B(0,0,0)		Mobile communication				
		NTT	KDDI	SoftBank	None	Sum
Fixed Broadband	NTT	47.83%	8.77%	8.76%	0.76%	66.12%
	KDDI	6.16%	4.98%	2.14%	1.11%	14.39%
	SoftBank	2.51%	0.14%	2.15%	0.88%	5.68%
	Other	4.38%	0.03%	2.28%	0.00%	6.68%
	None	3.19%	1.70%	0.67%	1.58%	7.13%
	Sum	64.06%	15.62%	16.00%	4.32%	100.00%

Table 10 Bertrand-Nash equilibria when the incumbent uses pure bundling

	B	(PB,1,1)	(PB,1,0)	(PB,0,1)	(PB,0,0)
Prices of Fixed Broadband	NTT				
	KDDI	3.816	3.989	3.756	3.774
	SoftBank	2.450	2.497	2.795	2.158
	Other	4.991	5.002	5.264	4.864
Prices of Mobile communications	NTT				
	KDDI	7.066	7.074	6.885	6.898
	SoftBank	5.492	5.486	5.479	5.468
Prices of Bundle	NTT	8.015	8.015	8.003	8.014
	KDDI	10.384	10.375		
	SoftBank	8.084		7.907	
Firms' Profits	NTT	3.877	3.874	3.903	3.877
	KDDI	**<u>2.138</u>**	**<u>2.151</u>**	2.094	2.092
	SoftBank	**<u>1.492</u>**	1.487	**<u>1.496</u>**	1.483
	Other	0.520	0.528	0.541	0.516
Sum of Profits		8.027	8.040	8.034	7.967
Consumer Surplus		4.608	4.600	4.598	4.657
Social Surplus		12.63	12.64	12.63	12.62

* Underline = best responses in first stage

Appendix

Table A1 All parameters of Mixed Logit without correlation

	Mixed Logit
Number of Observations	3740
Number of Parameters	42
Log-likelihood at convergence	-8575.95629
McFadden R	0.2346
Adjusted McFdden R	0.2341

		Estimates		Std. Err
δ_f	NTT	15.2725	***	2.3104
	KDDI	-136.4310	***	15.22836
	SoftBank	-23.5690		87.37001
	Other	-90.5020	***	25.9571
δ_m	NTT	19.9558	***	4.34788
	KDDI	11.8004	***	2.27581
	SoftBank	17.9757	***	2.88788
Γ	NTT	-0.1044		6.17561
	KDDI	20.3188	***	6.1504
	SoftBank	-36.7924		73.84531
α		-3.4218	***	0.06637
λ		3.4880	***	0.2948
Standard deviations of Parameters				
δ_f	NTT	0.3535		2.523
	KDDI	190.154	***	9.679
	SoftBank	36.0101		47.57935
	Other	105.711	***	16.01279
δ_m	NTT	24.6216	***	4.35232
	KDDI	46.64	***	2.43558
	SoftBank	0.52343		4.20851
Γ	NTT	0.30287		7.50843
	KDDI	71.2091	***	11.97353
	SoftBank	42.8449		30.68314

Heterogeneity in mean

Estimates			Std. Err
F_NTT:MEN	2.72337	***	0.1511
F_NTT:AGE	-0.05028	***	0.00439
F_KDDI:MEN	55.6006	***	3.99498
F_KDDI:AGE	-1.66759	***	0.13641
F_SoftBank:MEN	10.7819	***	0.90296
F_SoftBank:AGE	-0.49509	***	0.03408
F_Other:MEN	43.1231	***	1.92783
F_Other:AGE	-0.94424	***	0.11861
M_NTT:MEN	8.52981	***	0.46647
M_NTT:AGE	-0.38227	***	0.01514
M_KDDI:MEN	17.3868	***	0.85857
M_KDDI:AGE	-0.83286	***	0.02879
M_SoftBank:MEN	0.79993	***	0.20682
M_SoftBank:AGE	-0.02732	***	0.00722
G_NTT:MEN	3.21538	***	0.33447
G_NTT:AGE	0.00059		0.01339
G_KDDI:MEN	-12.4149	***	1.09306
G_KDDI:AGE	0.04448		0.03944
G_SoftBank:MEN	7.06333	***	1.36225
G_SoftBank:AGE	0.03881		0.05492

* = significant at the 10% level; **= significant at the 5% level; and *** = significant at the 1% level.

Table A2 All parameters of Mixed Logit with correlation

	Mixed Logit with Correlation
Number of Observations	3740
Number of Parameters	87
Log-likelihood at convergenc	−8364.92478
McFadden R	0.2534
Adjusted McFdden R	0.2525

		Estimates		Std. Err	Heterogeneity in mean	Estimates		Std. Err
δ_f	NTT	23.4373	**	10.5133	F_NTT:MEN	5.74225	***	4.56806
	KDDI	−11.8075		14.4678	F_NTT:AGE	−0.17325	***	0.13613
	SB	16.9470		15.5345	F_KDDI:MEN	23.7439	***	5.55953
	Other	7.1900		9.6989	F_KDDI:AGE	−0.67742	***	0.16592
δ_m	NTT	44.4027	***	8.8849	F_SoftBank:MEN	8.31732	***	8.07581
	KDDI	52.6545	***	9.0467	F_SoftBank:AGE	−0.65016	***	0.17759
	SB	43.5472	***	7.3491	F_Other:MEN	12.005	***	4.68928
Γ	NTT	−23.6629	*	13.3886	F_Other:AGE	−0.46931	***	0.12995
	KDDI	13.4539		17.5637	M_NTT:MEN	18.7554	***	4.44687
	SB	−18.6142		56.7806	M_NTT:AGE	−1.07937	***	0.12647
α		−4.8782	***	0.1274	M_KDDI:MEN	21.0067	***	4.66952
λ		4.8699	***	0.2331	M_KDDI:AGE	−1.32676	***	0.10806
Standard deviations of Parameters					M_SoftBank:MEN	11.4813	***	5.37711
δ_f	NTT	8.33565		10.08179	M_SoftBank:AGE	−0.69634	***	0.12865
	KDDI	68.3508	***	9.95051	G_NTT:MEN	−19.7044	***	6.90178
	SB	31.5431	***	10.69081	G_NTT:AGE	1.22122	***	0.19335
	Other	38.7961	***	9.64624	G_KDDI:MEN	−27.6592	***	8.91984
δ_m	NTT	54.6814	***	9.76583	G_KDDI:AGE	1.24255	***	0.25639
	KDDI	66.9291	***	8.65307	G_SoftBank:MEN	−3.8691		30.258
	SB	30.8452	***	9.19806	G_SoftBank:AGE	0.63154	***	0.38101
Γ	NTT	58.9305	***	13.80601				
	KDDI	113.766	***	14.90701				
	SB	57.9294	**	23.31524				

* = significant at the 10% level; **= significant at the 5% level; and *** = significant at the 1% level.
F_X = parameters for fixed broadband of firm X
M_X = parameters for mobile communications of firm X
G_X = difference between bundle and sum of separate goods for firm X

Table A2 All parameters of Mixed Logit with correlation (Cont)

Diagonal values in L	Estimates		Std. Err
F_NTT	8.33565	***	10.08179
F_KDDI	47.8893	***	7.65345
F_SoftBank	18.101	***	6.46876
F_Other	2.87926	***	5.07933
M_NTT	34.9646	***	3.09738
M_KDDI	15.1648	***	3.15095
M_SoftBank	5.53291	***	3.44143
G_NTT	0.31751		5.77064
G_KDDI	2.69004	**	4.28186
G_SoftBank	7.62182	***	5.73858

Below diagonal values in L	Estimates		Std. Err
F_KDDI:F_NTT	−48.7693	***	20.21019
F_SoftBank:F_NTT	−25.3664	***	19.45004
F_SoftBank:F_KDDI	4.88561	***	12.84069
F_Other:F_NTT	−26.9797	***	18.6313
F_Other:F_KDDI	−8.53267	***	10.47373
F_Other:F_SoftBank	−26.3844	***	7.94435
M_NTT:F_NTT	−24.5978	***	17.51806
M_NTT:F_KDDI	−18.3316	***	11.49322
M_NTT:F_SoftBank	−20.5153	***	7.69766
M_NTT:F_O	20.1385	***	5.1681
M_KDDI:F_NTT	−40.4559	***	15.82109
M_KDDI:F_KDDI	−39.5953	***	7.42712
M_KDDI:F_SoftBank	7.15252	***	5.10983
M_KDDI:F_O	16.7322	***	5.05244
M_KDDI:M_NTT	26.7197	***	4.44207
M_SoftBank:F_NTT	−26.015	***	18.48413
M_SoftBank:F_KDDI	3.7148	***	6.92281

Below diagonal values in L（Cont)	Estimates		Std. Err
M_SoftBank:F_SoftBank	−4.65691	***	4.97396
M_SoftBank:F_Other	7.38255	***	5.38671
M_SoftBank:M_NTT	11.2228	***	4.64012
M_SoftBank:M_KDDI	−5.30049	***	4.67839
G_NTT:F_NTT	33.0007	***	22.87179
G_NTT:F_KDDI	18.028	***	8.90459
G_NTT:F_SoftBank	20.9387	***	7.82122
G_NTT:F_Other	−20.0071	***	7.28348
G_NTT:M_NTT	−34.9202	***	6.78465
G_NTT:M_KDDI	−0.71724		5.89373
G_NTT:M_SoftBank	0.01373		5.82192
G_KDDI:F_NTT	80.7863	***	18.965
G_KDDI:F_KDDI	69.3307	***	13.00605
G_KDDI:F_SoftBank	−28.9076	***	7.57112
G_KDDI:F_Other	−6.31277	***	8.0233
G_KDDI:M_NTT	−14.5067	***	6.12852
G_KDDI:M_KDDI	−11.6417	***	7.11316
G_KDDI:M_SoftBank	19.4888	***	6.14321
G_KDDI:G_SoftBank	1.05309		6.96882
G_SoftBank:F_NTT	39.0389	***	20.32353
G_SoftBank:F_KDDI	−26.3897	***	12.86748
G_SoftBank:F_SoftBank	20.6728	***	11.68895
G_SoftBank:F_Other	0.7424		6.97248
G_SoftBank:M_NTT	7.42359	***	14.50694
G_SoftBank:M_KDDI	23.1022	***	11.7851
G_SoftBank:M_SoftBank	−0.12518		10.20528
G_SoftBank:G_NTT	−7.60502	***	9.6609
G_SoftBank:G_KDDI	1.63899		7.50894

* = significant at the 10% level; **= significant at the 5% level; and *** = significant at the 1% level.