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Essays on Competition and Regulation in the Telecommunications Industry

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Essays on Competition and Regulation in the Telecommunications Industry

DISSERTATION

submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in Economics

by

Ji Won Baek

Dissertation Committee:
Professor Jan K. Brueckner, Chair
Professor Linda R. Cohen
Associate Professor Jiawei Chen

2014
DEDICATION

To

my family
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ABSTRACT OF THE DISSERTATION

Essays on Competition and Regulation in the Telecommunications Industry

By

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Doctor of Philosophy in Economics

University of California, Irvine, 2014

Professor Jan K. Brueckner, Chair

My dissertation is composed of three chapters that focus on competition and regulation in the telecommunications industry.

The first chapter investigates the main determinants of mobile service prices and evaluates the impact of market structure and regulations on retail prices. Both a simultaneous equations model and a reduced form model are estimated using a panel dataset for 36 countries over the period of 1999-2010. The market concentration of mobile network operators (MNOs) has a statistically significant effect on prices in the reduced form regression. The coefficients of regulatory variables, such as mobile number portability (MNP), mobile virtual network operators (MVNOs) and mobile termination rates (MTR), are not significant in both estimations, suggesting that it is hard to conclude that ex post regulations are effective in mature markets. Country-specific cost factors such as population density, interest rates and unit labor costs have positive impacts on prices.

The second chapter examines the structure of the household expenditure on telecommunications services and their relationship with other existing expenditures in South
Korea. To estimate the demand for telecommunications services, the linear approximate Almost Ideal Demand System is implemented. The short-run relationship is estimated using a seemingly unrelated regression (SUR) with first differenced series of data, and the long-run relationship is examined through a Vector Error Correction Model (VECM). Both empirical results suggest that the household demand for telecommunications services is income inelastic over the period of 1990.1Q to 2013.2Q while it becomes price elastic after 2006. The results also show that recent telecommunications services have a complementary relationship with public transportation and substitution relationship with cultural services and private education.

The third chapter analyzes the optimal features of three-part tariffs in the presence of heterogeneous consumers for the monopoly case and the duopoly case. Under monopoly case, the low demand users consume at the allowance level while the high demand users consume above it. The marginal utilities of consumption for the low demand type and high demand type exceed marginal cost, and the lump sum fee extracts all the surplus of low demand type. Under duopoly, asymmetric equilibria do not exist and only a symmetric three-part tariff can be achieved as an equilibrium where marginal utilities for all consumers equal marginal cost, confirming that a standard Bertrand outcome holds under the three-part tariff with heterogeneous consumers.
Chapter 1

The Impact of Regulation on the Prices of Mobile Voice Services

1.1. Introduction

Mobile telecommunications service has experienced dramatic growth during the last two decades. Technological innovations have played an important role in the spectacular demand growth of mobile service, and increased competition has been another key driver of the successful diffusion of mobile telephony service. The regulatory authority in each country has regulated the market power of incumbents, promoting competition by lowering entry barriers and inducing decreases in retail prices.

Since the mobile industry exhibits a cost structure with huge fixed cost and low marginal cost, regulatory policy to lower entry barriers has been demanded by new participants not having their own infrastructure. The initial regulations to restrict the market power of dominant firms have been comparatively successful in that they increased the number of firms and improved competition. However, regulatory policies have the potential to diminish incentives to invest, even though investment in network infrastructure should continue to grow to make the growth in the mobile industry sustainable. The two goals of ‘promoting competition’ and ‘providing incentives for investment’ are hardly compatible. Therefore, there are two major voices associated with the mobile telephone regulation: one is deregulation on retail prices and access networks of the operator with significant market power in order to attract more investment for

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1 Wireless service penetration rates exceed 100 percent in more than 37 countries as of the first quarter in 2012. (Merrill Lynch, Global Wireless Matrix 2Q 2012)
network upgrade. The other one is tougher regulation on the operator in order to pursue more active competition.

This paper identifies the main determinants of mobile service prices and discusses whether further regulatory intervention is necessary in current mobile markets. If the regulation of mobile telephony is likely lead to an overall welfare gain despite the adverse effect on investment incentives, regulatory decisions can be justified. The effect of regulation can be evaluated by using a simple econometric analysis to examine whether observable changes in retail prices of mobile telephony services may be attributed to regulatory policy.

The firms in the mobile industry need to set prices considering their markup to cover their high fixed capital cost, and the pricing policy for mobile operators should be based on firms’ cost structure. However, it is hard for a regulatory authority to evaluate whether the current prices are set based on the appropriate economic costs because, in many countries, the requisite cost information in the mobile industry is unavailable and unreliable. Additionally, rapid technological changes are making infrastructure cost allocation even more complicated. Therefore, regulators in many countries have referred to mobile service prices rather than observed profitability of dominant firms for indicators of market power such as concentration and barriers to entry, by directly observing price movements in mobile markets that are experiencing competition. Hence, analyzing how cross-national differences in the market structure and regulatory design explain the variation in retail prices should be of interest for policy makers by indicating whether regulatory intervention is needed.

There have been several previous studies that address the impact of regulatory factors on retail prices of mobile telephony services, using international panel data. Since previous studies, mobile telephony has entered a mature industry stage, and the mobile data service is growing as
a substitute to or complement for mobile telephony with mobile-device innovations. Furthermore, the market structure has been changed as more countries have introduced MVNOs (Mobile Virtual Network Operators) and mergers of network operators have been increasing. This paper extends the time period of analysis up to 2010 to reflect the steady evolution of competition and recent technological progress since previous studies.

The changed regulatory and non-regulatory environments raise the following questions: Are the current regulatory regimes in fact associated with a lower mobile price? Does higher market concentration of MNOs (Mobile Network Operators) lead to a higher mobile voice price? Does the emergence of a complementary or substitute good have a significant effect on demand for mobile voice service? What are the determinants of mobile voice service prices under recent regulatory mobile environments? To address these questions, this paper estimates a reduced form model and a simultaneous equations model using a panel dataset for 36 countries from 1999 to 2010 and examines the impact of market structure and regulations on retail prices in a mature mobile voice market.

The next section briefly reviews related literature. Section 1.3 describes the data and variables used to estimate the model. Section 1.4 and section 1.5 derive the empirical model and discuss the results of estimation. The final section concludes.

1.2. Related Research

The earlier studies associated with regulation of the mobile market mainly dealt with the effect of regulations on diffusion of mobile services and the substitution between fixed-line and mobile telephony. Madden and Coble-Neal (2004) and Gruber and Verboven (2001) analyze the determinants of the demand for mobile telephony and the effect of regulations on the diffusion of
mobile voice services. Madden and Coble-Neal (2004) develop an economic model of mobile telephone subscription demand that incorporates a network effect using a panel dataset comprised of 56 countries from 1995-2000. They find substantial substitution between fixed-line and mobile telephony and that price ceilings imposed in the fixed-line networks can retard the growth of the mobile network. Gruber and Verboven (2001) study the impact of regulation and technology in the diffusion of mobile services across the EU through 1998. Their results show that the impact of introducing competition has been significant, though the effect was smaller than the technology effect.

As mobile telephony has been approaching a mature industry stage after its phenomenal growth, the issues surrounding competition policy and its effect on consumer welfare became a topic of concern. Riccardi et al. (2009) examines how the regulatory setting can affect fringe entry in a mature regulated industry. They use panel data for 10 European Member States spanning 1998-2005 and analyze the impact of regulatory incentives and governance on the number of Mobile Virtual Network Operators’ (MVNOs). They find that the amount of fringe entry into a mature industry is the result of both strategic behavior of the incumbents and the implementation of credible regulations to prevent entry-deterring activities.

However, recent studies that examine the effect of regulatory factors on mobile telephony prices are rather scarce. The lack of comparable and consistent data restricts research in the recent time period. It is hard to get an appropriate proxy for prices and to collect comparable price data because mobile tariff schedules have evolved into complex structures and most mobile pricing consists of both a per-minute charge and a flat rate providing diverse bundles of services. Nevertheless, there are a few papers specifically focusing on pricing. McCloughan and Lyons (2006) attempt to evaluate the determinants of the price of mobile service by analyzing
international panel data from 14 countries from 1999 to 2004. They use ARPU (Average Revenue per User) as a proxy for the price of mobile services and find that there is no evidence that market concentration has any influence on ARPU, which means that market concentration is an unreliable indicator of competition in mobile telephony markets. This result suggests that mobile markets might not be characterized by oligopolistic pricing behavior, even though the market is highly concentrated. Lyons (2006) examines how the introduction of mobile number portability (MNP) affects prices in mobile markets. MNP allows customers who wish to switch mobile operators to keep their mobile numbers, so it is a policy reform to strengthen competition in mobile markets. Lyons (2006) uses RPM (average Revenue per Minute) as a proxy for prices and finds that mobile number portability reduces average prices and encourages churn \(^2\) as a proxy for switching when switching is rapid but not when it is slower. However, no proxies for market concentration prove to be significant. Grzybowski (2005) investigates the impact of regulatory policy on mobile voice prices for the European Union, estimating a reduced-form model using panel data for EU countries from 1998 to 2002. He finds that the liberalization of fixed telephony has a negative impact on mobile service prices and that the introduction of mobile number portability (MNP) turns out to be significant price determinant.

The previous literature relies on short-term period analysis up to 2004. However, in European countries, most of current regulatory policies are based on the EC new regulatory framework for electronic communication adopted in 2002.\(^3\) Considering that there is a time lag for a new regulation to catch on, the results in the previous literature on the impact of regulation

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\(^2\) To figure out switching propensity, the churn rate is used as a measure of switching. Churn represents the number of users disconnected from each network, and normally is expressed as a proportion of the average number of network users in a given period.

\(^3\) The new regulatory framework aims at laying the groundwork for harmonizing regulation in the EU, reducing entry barriers and facilitating sustainable competition for the good of users. The EC is responsible for providing a common European regulatory framework and for monitoring its implementation. However, all Member States must establish separate national regulatory authorities (NRAs). NRAs are responsible for the implementation of regulations within the country and legally independent.
on prices may not be relevant to the current regulatory regimes. This paper differs from the above-mentioned studies in creating regulatory variables that are most appropriate for the changing mobile regulatory environment and extending the time period to employ non-regulatory variables reflecting the effect of the emergence of new services. 

1.3. Variables

1.3.1. The data

The main source of data is Merrill Lynch *Global Wireless Matrix* (Merrill Lynch, 2Q 2004, 4Q 2007, 1Q 2009, 2Q 2012). This quarterly publication provides a wide range of data on mobile telephony service in up to 57 countries. Additionally, the *World Development Indicators* (World Bank, 2012) and *OECD Communications Outlook* (OECD, 1999, 2001, 2003, 2005, 2007, 2009, 2011) are used for general information on each country, such as GDP per capita, population density and the GDP deflator used to derive the real variables. Publications by a regulator in each country are also employed to check for changes in recent regulation.

This paper uses a panel dataset on 36 countries mainly focusing on OECD countries and several developing countries. The dataset is a panel data of twelve years from 1999 to 2010. (See Appendix A. Sample Coverage and Observation of Variables)

1.3.2. Prices

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4 This paper excludes the regulatory variables that are hardly identified due to the lack of variation across the countries. Whether prices are based on Calling Party Pays (CPP) or Receiving Party Pays (RPP) is important factor in pricing because it affects termination charges. However, this factor is excluded because it cannot be identified across the countries. Similarly, the SMP (Significant Market Power) designation is excluded because in most of countries, the incumbents with market share of over 25% ~ 50% are designated as an SMP and get regulatory remedies to correct ineffective competition. Therefore, an SMP designation cannot be identified as the determinant of retail prices.
The proxy for prices is annualized real RPM (real average Revenue per Minute), which is an aggregate measure including all revenue from mobile voice services but excluding revenue from data services.\textsuperscript{5} There are several advantages to using RPM as a proxy for prices.

Firstly, this measure reflects important features of current mobile telephony pricing, which varies across countries. The pricing structure of mobile service has undergone significant change, with operators offering diverse tariff schedules so that they can attract more consumers. Therefore, it is hard to pick one or more tariff packages and use them as a proxy for the level of mobile prices. RPM allows aggregation across all tariff packages offered within one country. Additionally, by using RPM, the innovations in tariff structures, such as bundling schemes and prepaid services, can be taken into account.\textsuperscript{6} Therefore, all customers currently using mobile services can be captured regardless of types of tariff packages.

Average revenue per user (ARPU) also might be used as an alternative measure for comparison of the mobile prices. The monthly average revenue per user is calculated by dividing service revenues by the average subscriber base. McCloughan and Lyons (2006) used average revenue per user (ARPU) as an indicator of effective price, and some regulators use ARPU as an indicator of ‘significant market power’ when they make a decision about price regulation.\textsuperscript{7} However, ARPU reflects mobile service expenditure rather than the level of mobile voice prices, so it is associated with both price level changes and usage changes in mobile service.

Real RPM is an appropriate measure to capture the current trend under which operators are increasingly providing pricing plans mainly consisting of fixed minutes of use and a flat-rate fee without additional usage-related charges as long as allowed minutes are not exhausted. Such

\textsuperscript{5} Merrill Lynch \textit{Global wireless Matrix} provides good sources for RPM, and this data is made as comparable as possible on a global basis. They calculate RPM by dividing estimated monthly voice ARPU (reported service revenue per average subscriber, adjusted to exclude non-voice revenue) by reported MOU (minutes per user).

\textsuperscript{6} Lyons (2006), p 20. The ‘prepaid services’ makes the mobile service available without committing the customers a long-term contract.

\textsuperscript{7} McCloughan and Lyons (2006), p 531
an aggregate measure is more appropriate than a specific basket-based measure because per-minute pricing basket-based plans have tended to disappear in many countries.

1.3.3. Regulatory Variables

The variables in this study come from three categories: marginal cost determinants, markup determinants and demand determinants. This section describes important regulatory variables which might affect marginal cost conditions and markup determinants.

In the mobile voice market, there are two potential factors creating barriers to entry: The limited availability of frequency spectrum and consumer switching costs. Frequency spectrum is essential to provide mobile services, and operating a mobile network is not possible without access to spectrum. The usage rights of spectrum are allocated by the government or regulator in each country. Therefore, the number of mobile telephone networks is limited by the number of licenses issued by the government, and this limited availability of frequency spectrum has been a major factor causing high market concentration. Therefore, aiming to lower barriers to entry, access to mobile networks has been key remedy imposed by many regulatory bodies. The permission for entry of mobile virtual network operators (MVNOs) into mobile communications service allows the new entrants to provide service with small cost. Mobile virtual network operators (MVNOs) are operators who provide mobile services to users without allocated spectrum. Initially, many incumbent MNOs refused to grant access to their network or negotiated lengthy contracts fearing the cannibalization of their own customers. Therefore, some countries decided to force the incumbents to open their own mobile networks to MVNOs, adopting

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8 MNOs (Mobile Network Operators) refer to providers of wireless communications services that own or control access to radio spectrum license and wireless network infrastructure which is necessary to provide services to subscribers. MNOs may also sell access to network services at wholesale rates to MVNOs.
favorable access price regulation.\textsuperscript{9} Thus, the introduction of MVNOs in the mobile market implies that the cost of entry becomes lower, putting downward pressure on retail prices. The variable $MVNO_{it}$ is a dummy variable indicating whether such a mandate has been imposed in country $i$ during year $t$.

Another potential factor creating barriers to entry into mobile telephony is possible consumer switching costs. Giving up one’s mobile telephone number is one of the switching costs. Switching costs make market entry more difficult because the incumbent MNOs’ customers only change providers to a new entrant when the price advantage from choosing a new entrant exceeds switching costs. Therefore, to lower switching costs, many countries require mobile service operators to offer Mobile Number Portability (MNP), which allows customers to switch mobile service operators while keeping their original mobile number.\textsuperscript{10} The goal of this regulation is to remove the cost of switching to new numbers and thus, to promote stronger competition in the business. In principle, the effect of MNP on competition should be a decrease in prices. However, MNP is likely to increase marginal costs because it generates costs associated with facility needed for implementation of MNP, which might be passed on to consumers, leading to an increase in prices. The dummy variable $MNP_{it}$ indicates the implementation of MNP in country $i$ during year $t$, allowing net effect of reducing switching cost to be measured.

The last regulatory measure that might affect prices is mobile termination rates (MTRs). Termination rates are the charges that one operator charges to another operator for terminating calls on its network. Therefore, termination rates form part of an operator’s cost of providing the calls to its customers and affect the price of outgoing calls since the operator on the caller’s side

\textsuperscript{9}This is an asymmetric regulation as normally regulators are only concerned with incumbents.

\textsuperscript{10}Mobile Number Portability (MNP) regulation is a symmetric regulation as the regulators concern all the mobile operators.
must pay termination rates to the operator on the receiver’s side.\textsuperscript{11} MTRs may be commercially negotiated or may be regulated. To prevent each network operator from imposing excessive termination rates, operators are obligated to set cost-oriented mobile termination charges and to publish these charges. The variable $\text{MTR}_{it}$ is a dummy variable indicating whether such obligations have been imposed.

One important issue to mention here is whether these regulatory variables are exogenous or not. The regulator adjusts regulatory policy according to the current market indicators such as prices, demand and supply. The regulatory variables may be considered to be endogenous because the regulation policies might be implemented with the goal of promoting competition and lowering prices when regulators deem that the overall price level is high. Hence, the reduced form model might have a potential reverse causality problem, which could cause a bias in the OLS estimation. However, in this study, regulatory variables are treated exogenous because normally it takes long time for regulators to decide to adjust their regulation according to evaluation of market competition.\textsuperscript{12} Hence, the decision to adopt the regulatory strategies was in most cases made substantially before the current price was set.

\textbf{1.3.4. Other Explanatory variables}

To control the differences of the potential determinants of the marginal cost of providing mobile service, population density ($\text{POPDEN}_{it}$), real interest rate ($\text{REINT}_{it}$) and real unit labor cost ($\text{RULC}_{it}$) are used as explanatory variables. The log of population density may measure cost conditions and might also be inversely related to the price level as a result of economies of

\textsuperscript{11} In countries like the United States, Canada and Singapore, where the receiving party pays (RPP) system is employed, MTRs are not a significant factor in retail pricing because operators pay nothing to other operators to terminate their calls. However, in most other countries, where the calling party pays (CPP) system is used, the MTRs affect the price of outgoing calls since operators must pay to have calls terminated on another network.

\textsuperscript{12} The same claim was made by Grzybowski (2005). Grzybowski (2005), p56
density. Additionally, the square of log of population density is included to allow the marginal effect to depend on the level of population density. The real interest rate and real unit labor cost are proxies for input factor prices, and these variables are expected to have positive coefficients in the regressions.

The Herfindahl-Hirschman index (HHI) is included to measure how market concentration affects the mobile price through higher markups. To create $HHI_{it}$, the sum of the squared of the market shares of MNOs is calculated. To check robustness, in same specification, $HHI_{it}$ is replaced by $CR1_{it}$, the market share of the largest mobile service operator in each country. COM2$_{it}$, COM3$_{it}$ and COM4$_{it}$ are dummy variables indicating the number of mobile network operators (MNOs) providing services, corresponding to 2, 3 and at least 4 operators, respectively. The number of MNOs is determined exogenously by spectrum licensing. Therefore, in some sense, the initial market concentration in a mobile voice market depends on regulatory decision. Using the number of licensed operators as a proxy for concentration might answer the question of how many operators were sufficient to provide competition and limit the exercise of market power.

Since there might be technological innovation in the mobile service industry over time, leading to a decrease in marginal cost, the regression includes year dummy variables ($y2000_t, ..., y2010_t$) to control for this factor. This allows for time-varying unobserved effects such as changes in service quality to be controlled in the regression. Additionally, the time-invariant changes in service quality which is specific to an individual country can be also controlled by using fixed effects estimation.

Other explanatory variables are determinants of the demand for mobile services. Since income levels might influence demand positively, the log of GDP per capita in US dollars
(REGDP它) is included. The percentage of prepaid mobile subscriptions to total mobile subscriptions (PREPAID它) is a country-specific attribute which affects the demand for mobile voice service.

The demand for mobile voice service also depends on the prices of substitutes and complements. The price of fixed line services is one of the relevant variables. However, proxies for capturing fixed line services are unavailable for the relevant set of countries and periods.

Another potentially important variable is the price of mobile data service, including text messaging and mobile internet. The ratio of data revenue to average revenue per user (DATARATE它) is used as a proxy for the price of mobile data services. Even if this is not an ideal proxy, employing DATARATE它 makes sense in that the operators often charge a flat fee for data service instead of charging a usage-based rate. Additionally, users focus on their monthly bill for mobile data service rather than trying to figure out a per-bit price. DATARATE as a fraction of ARPU represents the price of the actual quantities of data service delivered in a given place and time, and it has an advantage of allowing aggregation across all tariff plans for mobile data service. As mobile devices like the smart phone soar in popularity, operators are concerned about how mobile voice and data service are linked by network effects. A significant negative coefficient on DATARATE它 would imply that prices for mobile voice service and mobile data service are inversely related. Finally, SUBS它, the number of mobile network users, is used as a proxy for quantity of services. Table 1.1 below lists the variables and provides summary statistics.

---

13 On the contrary, if most users are using usage-based rates plans, DATARATE它 might not be an appropriate proxy for data service price. In fact, DATARATE它 is more of expenditure on data service than price level. However, on condition that most of data plans are flat rates and purchase decision for mobile data service focuses on the total cost of using it, I can safely say that DATARATE它 can be a proxy for data service prices because it represents the actual fee users are paying for a limited usage.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Source</th>
<th>Mean</th>
<th>St. Dev.</th>
<th>Min.</th>
<th>Max.</th>
<th>Obs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REALRPM(_{it})</td>
<td>Real monthly revenues per minute (US$)</td>
<td>ML converted into real term by GDP deflator</td>
<td>0.180</td>
<td>0.114</td>
<td>0.006</td>
<td>1.198</td>
<td>425</td>
</tr>
<tr>
<td>HHI(_{it})</td>
<td>Herfindahl Hirschman Index</td>
<td>Own calculations based on ML, Sum of the squares of the market shares</td>
<td>0.366</td>
<td>0.088</td>
<td>0.166</td>
<td>0.627</td>
<td>425</td>
</tr>
<tr>
<td>CR(_{it})</td>
<td>A market share of the largest mobile service operator</td>
<td>ML</td>
<td>0.456</td>
<td>0.112</td>
<td>0.23</td>
<td>0.781</td>
<td>426</td>
</tr>
<tr>
<td>COM2(_{it})</td>
<td>=1 if two mobile network operators are active, else 0</td>
<td>ML</td>
<td>0.056</td>
<td>0.229</td>
<td>0</td>
<td>1</td>
<td>432</td>
</tr>
<tr>
<td>COM3(_{it})</td>
<td>=1 if three mobile network operators are active, else 0</td>
<td>ML</td>
<td>0.410</td>
<td>0.492</td>
<td>0</td>
<td>1</td>
<td>432</td>
</tr>
<tr>
<td>COM4(_{it})</td>
<td>=1 if four or more mobile network operators are active, else 0</td>
<td>ML</td>
<td>0.535</td>
<td>0.499</td>
<td>0</td>
<td>1</td>
<td>432</td>
</tr>
<tr>
<td>MNP(_{it})</td>
<td>=1 if mobile number portability implemented, else 0</td>
<td>OECD</td>
<td>0.539</td>
<td>0.499</td>
<td>0</td>
<td>1</td>
<td>432</td>
</tr>
<tr>
<td>MVNO(_{it})</td>
<td>=1 if mobile virtual network operators in place, else 0</td>
<td>OECD, ML</td>
<td>0.505</td>
<td>0.500</td>
<td>0</td>
<td>1</td>
<td>432</td>
</tr>
<tr>
<td>REINT(_{it})</td>
<td>Real interest rate</td>
<td>OECD Statistics</td>
<td>0.010</td>
<td>0.047</td>
<td>-0.494</td>
<td>0.171</td>
<td>326</td>
</tr>
<tr>
<td>RULC(_{it})</td>
<td>Real unit labor cost</td>
<td>OECD Statistics</td>
<td>100.97</td>
<td>17.04</td>
<td>13.35</td>
<td>142.25</td>
<td>287</td>
</tr>
<tr>
<td>LNPOPDEN(_{it})</td>
<td>Population density per km(^2)</td>
<td>World Bank</td>
<td>4.475</td>
<td>1.665</td>
<td>0.916</td>
<td>8.889</td>
<td>432</td>
</tr>
<tr>
<td>SUBS(_{it})</td>
<td>Number of mobile voice users (thousands)</td>
<td>ML</td>
<td>32,864</td>
<td>45,935</td>
<td>1,255</td>
<td>310,971</td>
<td>424</td>
</tr>
<tr>
<td>DATARATE(_{it})</td>
<td>The ratio of data revenue to average revenue per user</td>
<td>ML</td>
<td>0.150</td>
<td>0.083</td>
<td>0.01</td>
<td>0.489</td>
<td>364</td>
</tr>
<tr>
<td>PREPAID(_{it})</td>
<td>The percentage of prepaid mobile subscriptions to total mobile subscriptions</td>
<td>ML</td>
<td>0.536</td>
<td>0.257</td>
<td>0.009</td>
<td>1</td>
<td>398</td>
</tr>
<tr>
<td>LNREALGDP(_{it})</td>
<td>Real GDP per capita (US$)</td>
<td>World Bank</td>
<td>9.739</td>
<td>1.063</td>
<td>6.600</td>
<td>11.247</td>
<td>431</td>
</tr>
</tbody>
</table>

1.4. The Empirical Model

To derive a proper model to estimate, the demand and supply relations in the market for mobile voice services are considered. Total quantity demanded is assumed to be the following function of price:

\[
\ln Q_{it} = \ln P_{it} a_0 + X_{it} a_1 + u_{it} , \quad t = 1, \ldots, T; \quad i = 1, \ldots, I,
\]  

(1.1)

where \( i = 1, \ldots, I \) is the country subscript, \( t = 1, \ldots, T \) is the time subscript, \( P_{it} \) is the price for mobile voice service, and \( X_{it} = \{ \ln \text{REGDGP}_{it}, \text{DATARATE}_{it}, \text{PREPAID}_{it} \} \) is the set of exogenous explanatory variables. The error term, \( u_{it} \), represents unobservable demand shifters, and includes country fixed effects. The coefficient of \( \ln P_{it}, a_0 \), is the price elasticity of demand.

The supply relationship producing output \( Q \) can be expressed as

\[
P_{it} = MC(Q_{it}, W_{it}, R_{it}) \times \text{markup } (Z_{it}, R_{it})
\]  

(1.2)

where \( MC \) is the marginal cost function and \( \text{markup} \) depends on barriers to entry and concentration. \( W_{it} \) is a vector of country-specific cost drivers and \( R_{it} \) stands for regulatory factors which affect the marginal cost. \( Z_{it} \) is a vector of the variables which represent market concentration. We can write the marginal cost of providing service as follows:

\[
\ln MC_{it} = \ln Q_{it} b_0 + R_{it} b_1 + W_{it} b_3 + \gamma_{it} ,
\]  

(1.3)

where \( R_{it} = \{ \text{MNP}_{it}, \text{MVNO}_{it}, \text{MTR}_{it} \} \) is the set of regulatory variables, \( W_{it} = \{ \ln \text{POPDEN}_{it}, \ln \text{POPDEN}^2_{it}, \text{REINT}_{it}, \text{RULC}_{it} \} \) is the set of cost determinants and \( \gamma_{it} \) are unobservable cost shifters. The markup equation is specified as a linear function of the following variables

\[
\ln \text{markup}_{it} = Z_{it} c_0 + R_{it} c_1 + \Phi_{it}
\]  

(1.4)
where $Z_{it}$ are the variables which measure the market concentration, such as $\text{HHI}_it$ and $\text{COM3}_{it}$ and $\text{COM4}_{it}$, the dummy variables indicating the number of mobile network operators. Combining equation (1.3) and (1.4), the supply relationship is given by

$$\ln P_{it} = \ln Q_{it} d_0 + R_{it} d_1 + W_{it} d_2 + Z_{it} d_3 + \eta_{it}. \quad (1.5)$$

When we assume that supply meets whatever demand firms face, equation (1.1) and equation (1.5) leads to the reduced form specification:

$$\ln P_{it} = X_{it} e_0 + R_{it} e_1 + W_{it} e_2 + Z_{it} e_3 + \psi_t. \quad (1.6)$$

The first empirical analysis is based on this final reduced form price equation, where prices are regressed on exogenous explanatory variables, which appear on both the demand and supply sides. The reduced form parameters reflect the direct and indirect effect of the explanatory variables on prices. Even if the estimation of reduced form parameters does not have a causal interpretation, it shows the equilibrium change in prices given exogenous changes in explanatory variables, which this paper is interested in.

This paper also uses a structural framework to allow for simultaneous determination of quantities and prices in mobile voice markets, even if structural model is more data demanding. The two equations, (1.1) and (1.5), constitute the following simultaneous system:

$$\ln Q_{it} = \ln P_{it} a_0 + X_{it} a_1 + v_{it}, \quad v_{it} = a_i + \epsilon_{it} \quad (1.7)$$

$$\ln P_{it} = \ln Q_{it} d_0 + R_{it} d_1 + W_{it} d_2 + Z_{it} d_3 + \eta_{it}. \quad \eta_{it} = \theta + \mu_{it} \quad (1.8)$$

where $\alpha_i$ and $\theta_i$ are unobserved cross-country heterogeneity, and $\epsilon_{it}$ and $\mu_{it}$ are the idiosyncratic structural errors which are uncorrelated with the explanatory variables in both equations. This
model is estimated by a two stage least squares procedure, and once each equation is identified, we can estimate the structural parameters to measure a causal relationship.

1.5. Estimation Results

The first empirical model is estimated using a semi-logarithmic price equation based on the final reduced form equation (1.6). Collecting the variables discussed above and the taking the log of several variables including real RPM yields the following regression model for country $i=1\ldots36$ and year $t=1999\ldots2010$:

$$
\text{LNREALRPM}_{it} = \alpha + \beta_1 \text{LNHHI}_{it} + \beta_2 \text{MNP}_{it} + \beta_3 \text{MVNO}_{it} + \beta_4 \text{MTR}_{it} + \beta_5 \text{REINT}_{it} + \beta_6 \text{RULC}_{it} + \beta_7 \text{LNPOPDEN}_{it} + \beta_8 \text{LNPOPDEN2}_{it} + \beta_9 \text{DATARATE}_{it} + \beta_{10} \text{PREPAID}_{it} + \beta_{11} \text{LNREALGDP}_{it} + \sum_{j=1}^{12} \beta_{11+j} Y_t + \delta_i + u_{it}, \quad (1.9)
$$

This reduced form estimation relates RPM to explanatory variables including regulatory variables, non-regulatory country specific variables and year dummies, $Y_{1999}, \ldots, Y_{2010}$. This study assumes that all regulatory variables are exogenous, as mentioned in the previous section. A country fixed effect term $\delta_i$ is included, and the error term $u_{it}$ is specified as a classical disturbance that is a sequence of independently distributed normal variables with zero mean and variance $\sigma^2$.

In the second empirical analysis, the structural parameters of the system are estimated based on the following simultaneous equations:

$$
\text{LNREALRPM}_{it} = \zeta_0 + \zeta_1 \text{LNSUBS}_{it} + \zeta_2 \text{LNHHI}_{it} + \zeta_3 \text{MNP}_{it} + \zeta_4 \text{MVNO}_{it} + \zeta_5 \text{MTR}_{it} + \zeta_6 \text{REINT}_{it} + \zeta_7 \text{RULC}_{it} + \zeta_8 \text{LNPOPDEN}_{it} + \zeta_9 \text{LNPOPDEN2}_{it} + \sum_{j=1}^{12} \zeta_{9+j} Y_t + \alpha_i + \epsilon_{it} \quad (1.10)
$$
\[
\text{LNSUBS}_it = \lambda_0 + \lambda_1 \text{LNREALRPM}_it + \lambda_2 \text{DATARATE}_it + \lambda_3 \text{PREPAID}_it + \lambda_4 \text{LNREALGDP}_it \\
+ \sum_{j=1}^{12} \lambda_{4+j} Y_t + \theta_t + \mu_{it} \tag{1.11}
\]

Note that price is the dependent variable in the supply equation (1.10), while quantity, proxied by LNSUBS (log of the number of subscribers), is the dependent variable in the demand equation (1.11).

### 1.5.1. Reduced Form Estimates

In the fixed effects OLS model in Table 1.2, which shows the reduced form estimates, a few explanatory variables have a significant impact on price, and the explanatory variables explain 80% of the cross-country variation in the log of real prices. Estimation was also carried out with random effects, but this specification was rejected in favor of fixed effects by the Hausman test.\textsuperscript{14} Yearly dummy variables are also employed, but their coefficients are not reported.

The diagnostic tests after fixed effects OLS estimation of equation (1.9) showed evidence of autocorrelation and heteroscedasticity.\textsuperscript{15} Therefore, the reported t-statistics are based on the panel-robust variance matrix estimator for fixed effects estimators, which is valid in the presence of any heteroskedasticity or autocorrelation within the observations of each country.\textsuperscript{16,17}

\textsuperscript{14} The Hausman test shows \(\chi^2(19) = 96.93\) and Prob>\text{chi2} = 0.0000. This leads to strong rejection of the null hypothesis that a random effects specification provides consistent estimates.

\textsuperscript{15} Modified Wald test for groupwise heteroscedasticity shows Wald \(\chi^2(24) = 261.21\) [0.000]; Wooldridge test for autocorrelation in panel data shows \(F(1, 23) = 27.001\) [0.000].


\textsuperscript{17} Because autocorrelation was found within each country from OLS estimation, the model was initially estimated using Arellano-Bond estimator with robust standard errors, including the dependent variables lagged as the regressors. This estimator requires the errors to be serially uncorrelated and, thus, we expect the null hypothesis \(\text{Cov}(\Delta \epsilon_{it}, \Delta \epsilon_{it-k}) = 0\) for \(k=1,2,3\) to be rejected at order 1 and accepted at order 2,3. However, the Arellano-Bond test for zero autocorrelation did not reject the null hypothesis at order 1. Additionally, estimation results showed that the one-period lag of LNREALRPM has no statistically significant effect on LNREALRPM, suggesting that the dynamic model might not be appropriate for the estimation in this study.
The coefficients of regulatory policies, \( MNP_{it} \), \( MVNO_{it} \) and \( MTR_{it} \), are all negative, but they are statistically insignificant, which suggests that such regulations have no effect on prices and might not be needed. GrzyBowski (2005) and Lyons (2006) find a significant negative impact of \( MNP_{it} \) on the real prices of mobile service, however, suggesting contradictory results. The contradictory result may be obtained because this study employs a different proxy for price and the analysis is performed for a longer time period. This contrast in results may suggest that the effect of regulations has been shrinking as the mobile industry approaches maturity.

An increase in the market concentration of MNOs (\( LNHHI_{it} \)) has a statistically significant effect on prices. The fixed effects OLS model in Table 1.2 shows that a 1% of increase in HHI is associated with a 0.36% increase in real RPM. As previously mentioned, market concentration in mobile voice market is determined by the number of spectrum licenses issued by the government. Once the number of mobile telephone network operators is set, it is hard for a new MNO to enter the mobile market because a new allocation of frequency spectrum is needed. Therefore, the initial regulatory decisions about how many mobile network operators (MNOs) to allow is important in guaranteeing effective competition in the mobile voice industry.

The real interest rate (\( \text{REINT}_{it} \)) and real unit labor cost (\( \text{RULC}_{it} \)) are also significant determinants of real RPM. A 1% increase in the real interest rate leads, on average, to an increase in real RPM of 1.34%. A 1% increase in real unit labor cost leads to a rise in real RPM of 0.7%.

Population density (\( LNPOPDEN_{it} \)) is a proxy for local cost conditions and has the expected negative coefficient in the OLS model, reflecting economies of density, although the coefficient is not significant. To account for a non-linear relationship between average price and
Table 1.2 Panel regression results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Fixed effects OLS</th>
<th>Two Stage Lease Squares (2SLS)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coef.  t</td>
<td>Coef.  t</td>
</tr>
<tr>
<td></td>
<td>Demand</td>
<td>Supply</td>
</tr>
<tr>
<td>C</td>
<td>-5.433 -0.84</td>
<td>6.921 7.70</td>
</tr>
<tr>
<td>LNHHI</td>
<td>0.363 2.23**</td>
<td></td>
</tr>
<tr>
<td>MNP</td>
<td>-0.011 -0.17</td>
<td></td>
</tr>
<tr>
<td>MVNO</td>
<td>-0.049 -1.11</td>
<td></td>
</tr>
<tr>
<td>MTR</td>
<td>-0.003 -0.04</td>
<td></td>
</tr>
<tr>
<td>REINT</td>
<td>1.341 1.81*</td>
<td></td>
</tr>
<tr>
<td>RULC</td>
<td>0.007 1.75*</td>
<td></td>
</tr>
<tr>
<td>LNPOPDEN</td>
<td>-2.635 -1.02</td>
<td>-2.889 -1.67*</td>
</tr>
<tr>
<td>LNPOPDEN2</td>
<td>0.522 2.36**</td>
<td></td>
</tr>
<tr>
<td>DATARATE</td>
<td>-1.535 -1.54</td>
<td>0.353 1.41</td>
</tr>
<tr>
<td>PREPAID</td>
<td>0.089 0.49</td>
<td>0.410 5.08***</td>
</tr>
<tr>
<td>LNREALGDP</td>
<td>0.448 1.32</td>
<td>0.175 2.03***</td>
</tr>
<tr>
<td>LNSUBS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LNREALRPM</td>
<td>-0.101 -1.05</td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.806</td>
<td>0.935</td>
</tr>
<tr>
<td>Heteroskedasticity: Wald $\chi^2$</td>
<td>Wald $\chi^2 (24) = 261.21$</td>
<td></td>
</tr>
<tr>
<td>Autocorrelation: F(1, 23)</td>
<td>F(1, 23) = 27.001</td>
<td></td>
</tr>
</tbody>
</table>

Note: t-statistics are robust and *, ** and *** denotes significant at the 10%, 5% and 1% level, respectively.
POPDEN_{it}, the regression includes a second order term. The coefficient of LNPOPDEN^2_{it} is positive and significant, which implies higher population density increases the real RPM at very high levels of population density. As Figure 1.1 shows, the relation between log of real RPM and log of LNPOPDEN is convex in the relevant region of population density. The curve in Figure 1.1 is fitted for the mean value of the continuous variables, and zero for the regulatory dummy variables as of 2010. The two points of outliers, the high values of population density for Singapore and Hong Kong, are dropped to show trend line clearly without distorting the overall conclusion. The range of log of population density is from 0.92 (2 people per km$^2$) to 6.23 (509 people per km$^2$). Real RPM is minimized to $0.006 when the population density (Population per km$^2$) reaches 13.4. However, if the population density increases beyond this threshold, it results in the loss of economies of density.

**Figure 1.1 Log of real price of mobile voice service and log of population density**

The estimated coefficient of real GDP per capita indicates that a 1% increase in current per capita income raises real RPM by 0.448%. The sign for DATARATE_{it} is negative,
suggesting that an increase in mobile data service prices yield a decrease in mobile voice prices.\textsuperscript{18,19} However, the coefficients of real GDP per capita and data price are not statistically significant in the fixed effects OLS model. Finally, all coefficients of year dummies except for 1999, $Y_{2000}, \ldots, Y_{2010}$, which are included to allow for a time-varying unobserved effect common to all countries, are negative and statistically significant. Since 1999, the downward trend of mobile voice price has continued despite some fluctuations.

1.5.2. Structural estimates

The panel two stage least squares estimation in Table 1.2 give the estimates of the system of equations of (1.10) and (1.11). As noted above, the 2SLS model in Table 1.2 includes SUBS\textsubscript{it}, the number of mobile voice users served, as a proxy for quantity variable. In the demand equation, the coefficient on price (RPM) is negative but insignificant. However, the number of mobile voice users is much higher when the percentage of prepaid mobile subscriptions to total mobile subscriptions is higher. The income elasticity of demand is positive and inelastic. The positive sign for DATARATE\textsubscript{it} in 2SLS model gives opposite interpretation to that in the fixed effects OLS model. But both coefficients are not statistically significant.

The supply equation shows similar results to the reduced form price equation (1.9). Even though the estimated supply slope is negative, i.e. the price of mobile voice service is a decreasing function of quantity, this effect is not statistically significant. The coefficients of regulatory policies, MNP\textsubscript{it}, MVNO\textsubscript{it} and MTR\textsubscript{it}, are insignificant, still implying no obvious

\textsuperscript{18} The marginal effect of data price in the voice price is calculated as follows:

\[
\frac{\Delta \text{REALRPM}}{\Delta \text{DATAREV}} = \frac{\Delta \text{REALRPM}}{\Delta \text{LNREALRPM}} \times \frac{\Delta \text{LNREALRPM}}{\Delta \text{DATAREV}} = \text{real RPM } \times \beta_4, \quad 0.346 = -1.535 \times 0.180 \quad \text{where 0.180 = mean voice price. Therefore, for every one percentage point increase in the ratio of data revenue to average revenue per user, the voice price (real revenue per minute) decrease by 0.276 (US$).}

\textsuperscript{19} The price of fixed-line service, another potentially relevant variable, was unavailable for the datasets that is made as comparable on a global basis. Therefore, this study doesn’t check the substitutability between fixed-line service and mobile service.
evidence for effects of these regulations. The coefficient of LNHHI_{it} is positive, but the
magnitude is small and only significantly different from zero at a 20% significant level in the
2SLS model. Population density (LNPOPDEN_{it}) has a significant negative coefficient, reflecting
economies of density, and the coefficient of LNPOPDEN2_{it} is positive and significant. This
implies higher population density increases the real RPM when the population density increases
beyond a certain threshold. The coefficients of real interest rate (REINT_{it}) and real unit labor cost
(RULC_{it}) are also similar to those in the previous OLS model, showing these variables are
significant determinants of supply.

Even though the two models in Table 1.2 shows reasonable and consistent results, estimates for three variants of fixed effects OLS are presented in Table 1.3 and Table 1.4 below in order to check the robustness of results in Table 1.2. MNP_{it}, MVNO_{it} and MTR_{it} are the main variables of interest in this study, and their coefficients turned out to be insignificant in Table 1.2. However, this result might be due to high correlation between three regulatory variables or between regulatory variables and other explanatory variables in equation (1.9). However, when either MNP_{it} or MVNO_{it} is excluded, yielding the Model I and II in Table 1.3, the coefficients of the remaining regulatory variables are still insignificant. These results suggest that effects of current ex post regulatory policies do not appear to be evident, contrary to expectations.

High correlation between the regulatory variables and real GDP per capita is also possible because developed countries with higher income levels tend to implement policies to promote competition and lower the prices of mobile service. However, when LNREALGDP_{it} is excluded in the Model III, the estimates of MNP_{it}, MVNO_{it} and MTR_{it} are still insignificant.

---

20 MTR_{it} is not excluded because correlations between MTR_{it} and other regulatory variables are low.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Model I</th>
<th></th>
<th>Model II</th>
<th></th>
<th>Model III</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coef.</td>
<td>Robust- t</td>
<td>Coef.</td>
<td>Robust- t</td>
<td>Coef.</td>
<td>Robust- t</td>
</tr>
<tr>
<td>C</td>
<td>-4.676</td>
<td>-0.74</td>
<td>-5.425</td>
<td>-0.85</td>
<td>-0.295</td>
<td>-0.04</td>
</tr>
<tr>
<td>LNHHI</td>
<td>0.352</td>
<td>2.15**</td>
<td>0.365</td>
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Note: t-statistics are robust and *, ** and *** denotes significant at the 10%, 5% and 1% level, respectively.

According to the results presented so far, market concentration (HHI_{it}) has a statistically significant effect on prices in the OLS regressions. To check the robustness of this result, Table 1.4 shows results using different proxies for market concentration: CR1_{it}, COM3_{it} and COM4_{it}. 

---

23
Table 1.4  Panel regression results – reduced from estimation (fixed effects OLS)

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<th>Variable</th>
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<th>Model II</th>
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<td>lnREALGDP</td>
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R²         | 0.805        | 0.815      |
F- value   | 35.08        |            |

Note: t-statistics are robust and *, ** and *** denotes significant at the 10%, 5% and 1% level, respectively.
COM2_{it} is omitted to avoid multicollinearity. A one percentage point increase in the market share of the largest mobile service operator (CR1_{it}) leads to a 0.7\% rise in real RPM.\textsuperscript{21} Additionally, when the number of MNOs increases from two to more than four, the retail prices decrease by 0.2\%, an effect that is statistically significant.\textsuperscript{22, 23}

### 1.6. Conclusion

This paper analyzes the main determinants of mobile service prices and discusses the impact of market structure and regulations on retail prices across countries over the period 1999-2010 in a mature mobile voice market.

The results show that the market concentration of mobile network operators (MNOs) has a statistically significant effect on prices in the reduced form regressions. In the mobile voice market, the market concentration of MNOs is a result of spectrum licensing by the government. Once the number of mobile telephone network operators is set, it is hard for a new MNO to enter the mobile market because a new allocation of frequency spectrum is needed. The estimation results imply that the ex ante regulatory decisions on spectrum licensing are important to provide competition.

\textsuperscript{21} The marginal effect of data price in the voice price is calculated as follows:

\[
\frac{\Delta \text{REALRPM}}{\Delta \text{CR1}} = \frac{\Delta \text{REALRPM}}{\Delta \text{LNREALRPM}} = \frac{\Delta \text{LNREALRPM}}{\Delta \text{CR1}} = \text{real RPM} \times \beta, 0.135 = 0.180 \times 0.748 \text{ where } 0.180 = \text{mean voice price.}
\]

Therefore, for every one percentage point increase in the market share of the largest mobile service operator, mobile voice prices increase by 0.135 (US$).

\textsuperscript{22} In the previous literature, the question how many operators is sufficient to guarantee effective competition within the mobile telephone is not consistently answered. Crandall and Hausman (2000) showed that in regional US mobile telephone markets, one additional operator has been sufficient to lower prices significantly when compared to a monopoly, while further market entry did not have significant effects on mobile telephone prices. Parker and Röller (1997) suggested that a small number of mobile network operators is likely to lead to collusion with correspondingly higher prices. According to McCloughan & Lyons (2006), the number of network operators had no significant effect on prices.

\textsuperscript{23} McCloughan & Lyons (2006) and Lyons (2006) employed same proxies for market concentration as this paper does. Their studies, however, concluded that market concentration has no significant effect on price, suggesting contradictory results. The reason for this difference might be that this study employs a different proxy for price and the analysis is performed for a longer time period.
On the other hand, the effects of ex post regulatory policies to lower barriers to entry, such as the implementation of mobile number portability (MNP), mobile virtual network operators (MVNOs) and the regulation of mobile termination rates (MTR) remains unclear. The coefficients of these regulatory variables are negative, but, none of them is significant, suggesting that it is hard to conclude that ex post regulations are effective in mature markets. One of the possible reasons for this result is that the mobile voice market is saturated and competitive, so that the incumbents do not have an incentive to raise prices regardless of these regulatory policies, making the effects of regulatory variables on mobile prices hard to identify.

Cost factors such as population density, interest rate and unit labor costs have positive impacts on prices. A higher real GDP per capita or a higher percentage of prepaid mobile subscriptions do not have significant effects on price in the reduced form, although these factors appear to shift demand given the 2SLS results. Finally, this paper finds no significant effect of data service prices and the number of subscribers on mobile voice prices.
### Appendix 1. Sample coverage and Observations (Years) of variables

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<th>RULC</th>
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Chapter 2

The Effects of the Internet and Mobile Services on Urban Household Expenditures: the Case of South Korea

2.1. Introduction

For the past 20 years, the internet and mobile services experienced remarkable advances in South Korea, and this growth have significantly affected the structure of the household expenditures. The share of the household budget assigned to telecommunications services has been steeply increasing in South Korea. According to OECD communications outlook 2013, the share of the household expenditures on telecommunications in South Korea was 6%, which was the highest share among all OECD member countries.

Although this reflects the development and high penetration of mobile and broadband services in South Korea, there has arisen one concern over this issue. The Korean government has been concerned that the expenditure on telecommunications services is becoming a burden to the low-income households. The share of the household expenditure on telecommunications services in income deciles 1-2, 5-6 and 9-10 was 7.1%, 6.1% and 5.0% respectively as of the end of 2012. The government has regulated the prices of telecommunications and induced operators to lower rates further. Despite the steady decreases in prices, however, the household expenditures on telecommunications services are much greater than the average in OECD member countries, and the effects of government policy is still controversial.

Another effect of the advances in the mobile and internet services is the changes in household expenditures on other existing goods and services. It is worth noting that recent
telecommunications services are evolving from simple voice and internet services into a multifunctional tool to provide diverse services such as simple communications, the acquisition of information, online transactions, and entertainment goods such as music, games and video. Moreover, the innovation and diffusion of internet technology has accelerated the migration of economic activities from offline to online markets.\textsuperscript{24} In light of these trends, we can infer that telecommunications services would affect the household expenditures on existing goods/services such as transportations, cultural services and education. However, the directions of those effects are ambiguous. Taking, for instance, expenditure on private education, households can spend more time and budget on private education services with the growth of online education markets. On the other hand, plenty of information and learning materials provided by the internet might substitute for the expensive offline education services, and households might reduce their average spending on private education services.

The purpose of this study is to investigate the structure of the household expenditure on telecommunication services and their relationship with other existing expenditures. The analysis of changes in demand for telecommunications services could have implications regarding the above two issues. Firstly, we can answer the question of whether or not telecommunications demand is sensitive to prices and income variations, and whether or not governmental intervention on prices is still necessary to ease the burden on low-income households. Secondly, with respect to the cross price elasticity of demand, the interrelationship between telecommunications services and other goods/services will be evaluated, so that we can infer the correlation between the development of telecommunication services and consumption of other existing goods and services.

\textsuperscript{24} Lee and Lee (2012), pp.65
This study is organized as follows. Section 2.2 reviews the related literature and section 2.3 describes the analysis model and data used. Section 2.4 and Section 2.5 develop the static and dynamic approaches and display the estimation results. Section 2.6 concludes with the main findings and their policy implications.

2.2. Literature Review

With remarkable advances in the internet and mobile voice services, there have been many empirical studies that address the relationship between telecommunications services and consumption of other existing good/services. Hong (2007) analyzes whether the growth of the internet complements or substitutes for consumption of existing entertainment goods by applying a difference-in-differences approach. Zentner (2006) attempts to measure the effect of the internet on the music industry, especially concentrating on measuring the impact of online file sharing on music sales in stores. These studies regarding the effect of growth in telecommunications services are conducted on micro-level data. While the analysis with micro level data can describe behavioral changes, it is often limited in the scope because of data restrictions. However, an aggregate approach with time series data has the merit of providing insight into structural changes over a long time period.

With aggregate data, aggregate demand modeling can be used to investigate substitution and complementarity between telecommunications and other existing commodities. The Almost Ideal Demand System (AIDS) developed by Deaton and Muellbauer (1980) has received considerable attention as a popular model for estimating demand functions using aggregate data, and it has been used for an analysis of demand for aggregate commodity groups. Ozuna and Gomez (1994) estimate a system of recreation demand functions using AIDS. Denton and
Mountain (2004) apply the static AIDS model to investigate how demand elasticities vary with the degree of inequality in the income distribution using income data for seven countries. Regarding the demand function for telecommunications services, Choo et al. (2010) apply the static AIDS, and find a dominant effect of complementarity in the influence of telecommunications on transportation from the U.S Consumer Expenditure Survey over the period 1984-2002.

While the specifications of the conventional AIDS model in the above studies are static, many studies have attempted to employ a dynamic approach with cointegration of time series data. G. Karagiannis et al. (2000), Li et al (2004) and Eakins and Gallagher (2003) apply the Error Correction Model (ECM) LA/AIDS to their studies on tourism demand and food consumption, respectively. To avoid the several drawbacks of ECM LA/AIDS, Kaabia and Gil (2001) and M. Iooty et al. (2009) implement a Vector Error Correction Model (VECM) in their studies on demand system. Although many studies of demand systems have applied the static and dynamic form of AIDS model, they mainly focus on tourists’ expenditure or food consumption, and studies of demand for telecommunications services are still rare.

Telecommunications services have become an important household expenditure that affects other expenditures through growing online activities. South Korea experienced one of the most rapid rises in broadband penetration in the world, and both mobile and broadband market had already started to saturate before the mid of 2000. Therefore, the increased demand for telecommunications services and its effect on other industries have been an important topic in terms of public policy in South Korea.

This study will be the first attempt to use the Vector Error Correction approach in the AIDS model in estimating the demand for telecommunications services in South Korea. This
study uses time series aggregate dataset ranging 1990.1Q to 2013.2Q, which has a broad classification of the household expenditures. The time period is long enough to reflect the structural changes associated with the introduction, diffusion and maturity of mobile voice and internet services, so that this study will identify the structural changes in demand over time along with the advances in telecommunications services.

2.3. Analysis Method and Data

This study employs the average household monthly expenditure (urban households with more than two family members) from 1990.1Q to 2013.2Q in the Korean Statistical Information System (KOSIS). This quarterly dataset provides expenditures for twelve broad categories and smaller items of each category.

This paper is mainly interested in 5 expenditure categories, which are telecommunications services, public transportation, cultural services, books and other printed matter, and private education. For the price variables, this study employs the quarterly consumer price index (CPI) (2010=100). Since the categories for household expenditures and CPI are not exactly same, CPI categories are reclassified into new categories based on the household expenditure categories in KOSIS. Table A2.1 in the Appendix summarizes the detailed components in each category.

Figure 2.1 shows how the budget shares of monthly household expenditure on telecommunications services have changed from 1990.Q1 to 2013.Q2. The analytical period can be divided into three segments according to the dramatic changes in budget shares as shown in Figure 2.1.
The first segment in time ranges from 1990.1Q through 1997.4Q. The share of the household expenditure on telecommunications services scarcely changed, with the average budget share for telecommunications services only around 2%. During this period, fixed telephony had been a main telecommunications service until competition in mobile telephony was implemented in the late 1997 and broadband service was introduced in 1998.

The second segment in time ranges from 1998.1Q through 2005.4Q, which is the diffusion period of mobile and broadband internet services. In the late 1997, three personal communications services (PCS) providers entered the mobile telecommunications market, which led to the rapid diffusion of mobile telephony. Broadband internet service was introduced in 1998, and, the budget share of telecommunications services has sharply increased since 1998.

The last segment in time is the maturity period of mobile and broadband internet services, which ranges from 2006.1Q through 2013.2Q. As of Dec. 2005, mobile penetration and
household penetration of broadband were 80% and 75%, respectively, which suggests this industry had entered maturity stage.\(^{25}\)

Using a time series dataset for aggregate demand system modeling, this study will use the Almost Ideal Demand System (AIDS) model developed by Deaton and Muellbauer (1980). This has been a commonly used method for analyzing consumer behavior as it has considerable advantages. This model is useful in that it has a functional form that is consistent with a household-budget dataset, and also possesses enough parameters to estimate the structural characteristics of demand, including the own-price, cross-price, and income elasticities. Additionally, it avoids the need for non-linear estimation, and the restrictions of homogeneity and symmetry can be tested through linear restrictions on the parameters in the model.

The estimations are implemented to investigate both the short-run and long-run relationship: the short-run model is estimated by a seeming unrelated regression (SUR) with first differenced data, and the long-run model is implemented through a vector error correction model (VECM).

2.4. The linear approximate Almost Ideal Demand System (LA/AIDS)

The Almost Ideal Demand System (AIDS) model starts from a specific class of preferences, which allows exact aggregation over consumers. It represents the market demand as if it were the outcome of decisions by a rational representative consumer. The preferences of a rational representative household, known as the price-independent generalized logarithmic (PIGLOG) class, is represented by expenditure function, which defines the minimum

\(^{25}\) To have sufficient number of observations, the analytical period will be divided into 1990Q1 -1997Q4, 1997Q4 – 2005Q4, and 2005Q4 – 2013Q2 in the estimations of the following sections.
expenditure necessary to attain a specific utility level at given prices. Equation (2.1) shows this expenditure function \( c(u, p) \) for utility \( u \) and price vector \( p \):

\[
\log c(u, p) = (1 - u) \log(a(p)) + u \log(b(p))
\]  

(2.1)

where \( u \) lies between 0 (subsistence) and 1 (bliss), so that the positive linearly homogeneous functions \( a(p) \) and \( b(p) \) can be regarded as the cost of subsistence and bliss, respectively.

Next, specific functional forms are taken for \( \log(a(p)) \) and \( \log(b(p)) \) as in equation (2.2) and equation (2.3) below, which allows functions to be of a flexible functional form which possesses enough parameters to approximate any elasticities at a given point. Then the AIDS expenditure function is as in equation (2.4):

\[
\log a(p) = a_0 + \sum_k a_k \log p_k + \frac{1}{2} \sum_k \sum_j Y_{kj}^* \log p_k \log p_j
\]

(2.2)

\[
\log b(p) = \log a(p) + \beta_0 \prod_k p_k^{\beta_k}
\]

(2.3)

\[
\log c(u, p) = \alpha_0 + \sum_k \alpha_k \log p_k + \frac{1}{2} \sum_k \sum_j Y_{kj}^* \log p_k \log p_j + u \beta_0 \prod_k p_k^{\beta_k}
\]

(2.4)

where \( \alpha_i, \beta_i, \) and \( Y_{ij}^* \) are parameters, and \( p_i \) is the price of a good \( i \). The demand functions can be derived directly from equation (2.4). According to Shephard’s lemma, the price derivatives of the expenditure function are the quantities demanded: \( \frac{\partial c(u, p)}{\partial p_i} = q_i \). Multiplying both sides by \( \frac{p_i}{c(u, p)} \) gives

\[
\frac{\partial \log c(u, p)}{\partial \log p_i} = \frac{p_i q_i}{c(u, p)} = w_i
\]

(2.5)

where \( w_i \) is the budget share of good \( i \). Thus, the AIDS demand function can be derived as a function of prices and utility in budget share form as shown in equation (2.6):

\[
w_i = \frac{\partial \log c(u, p)}{\partial \log p_i} = \frac{\partial \log c(u, p)}{\partial p_i} p_i = \alpha_i + \sum_j Y_{ij} \log p_j + \beta_i u \beta_0 \prod_k p_k^{\beta_k},
\]

(2.6)
where \( Y_{ij} = \frac{y^*_i + y^*_j}{2} \).

Since total consumption expenditure \( x \) is equal to \( c(u,p) \) for a utility-maximizing consumer, the indirect utility function can be derived as a function of \( p \) and \( x \). By substituting the result into equation (2.6), we have the budget shares as a function of \( p \) and \( x \), which are the AIDS demand functions in budget share form:

\[
w_i = \alpha_i + \sum_j Y_{ij} \log p_j + \beta_i \log \{x/P\},
\]

where \( P \) is a price index defined by

\[
\log P = \alpha_0 + \sum_k \alpha_k \log p_k + \frac{1}{2} \sum_j \sum_k Y^*_{kj} \log p_k \log p_j,
\]

\[
w_i = \frac{p_i q_i}{\sum p_i q_i} = \text{expenditure share for good } i,
\]

\[
X = \sum p_j q_j = \text{total expenditure on all goods},
\]

\[
p_i = \text{price of good } i, \quad q_i = \text{quantity demanded of good } i,
\]

For empirical estimation, Deaton and Muellbauer (1980) suggested the use of Stone’s price index \( P^* \) as an approximation of \( P \) in equation (2.8). This modified model is referred to as the linear approximate AIDS (LA/AIDS).

\[
\log P^* = \sum w_i \log p_i
\]

To comply with the theoretical properties of demand theory, i.e. the budget constraint and utility maximization, the following restrictions are imposed on the parameters of the LA/AIDS model: equation (2.9) imposes adding-up restrictions, so that the budget shares sum to unity \((\sum w_i=1)\). The equation (2.10) is a homogeneity restriction stating that a system of demand functions are homogeneous of degree zero in price and total expenditure taken together, which means a proportional changes in all prices and expenditure don’t affect the quantities purchased.
The last restriction in equation (2.11) is Slutsky symmetry, which takes consistency of consumers’ choices into account.

\[ \sum_i \alpha_i = 1, \sum_i Y_{ij} = 0, \sum_i \beta_i = 0 \quad (2.9) \]

\[ \sum_j Y_{ij} = 0 \quad (2.10), \quad Y_{ij} = Y_{ji} \quad (2.11) \]

Given these conditions, the model can be simply interpreted. The budget shares are constant in the absence of changes in relative prices and real expenditure \( \left( \frac{X}{P} \right) \). The changes in relative prices work through the term \( Y_{ij} \), with \( Y_{ij} \) representing the effect on the \( i \)th budget share of a percentage change in the \( j \)th price with real expenditure held constant. The \( \beta_i \) coefficients represent the effect of a change in real expenditure on the \( i \)th budget share with prices held constant.

LA/AIDS can be estimated using a seemingly unrelated regression (SUR) procedure, which adjusts for cross-equation contemporaneous correlation. This approach is capable of analyzing the interdependence of budget allocations to different goods/services, which a single equation approach cannot adequately capture. Once the AIDS parameters are estimated, we can obtain demand characteristics such as income elasticities and the Marshallian/Hicksian price elasticities with the following calculations.\(^{26}\) The sign of the calculated \( e_{ij}^M \) indicates the substitutability or complementarity between goods/services.

- Income elasticity : \( \eta_i = \frac{\partial \log q_i}{\partial \log x} = \frac{\beta_i}{w_i} + 1 \)
- Marshallian own-price elasticity : \( e_{ii}^M = \frac{1}{w_i} (Y_{ii} - \beta_i * w_i) -1 \)
- Marshallian cross-price elasticity: \( e_{ij}^M = \frac{1}{w_i} (Y_{ij} - \beta_i * w_j) \)

\(^{26}\) Hicsian own-price elasticity and cross-price elasticity are calculated as \( e_{ii}^H = e_{ii}^M + \eta_i = -1 + \frac{Y_{ii}}{w_i} + w_i \) and \( e_{ij}^H = e_{ij}^M + \eta_i = \frac{Y_{ij}}{w_i} + w_j \), respectively. Hicsian elasticities of demand aren’t reported here.
2.4.1. SUR with first differenced series for the short-run relationship

It is necessary to investigate the time-series properties of data to assess whether the demand relationships in this model are meaningful or merely spurious. Nonstationary time series data may invalidate the asymptotic distribution of the estimators, causing the statistics such as $t$, $F$ and $R^2$ unreliable.\footnote{Lee and Lee (2012) is the most recent study which examined the effects of telecommunications in South Korea by using the AIDS model. However, the SUR estimation in their study was implemented without considering the possible nonstationarity of time series data, which may mistakenly lead to failure to reject the null hypothesis.}

Figure A2.1 ~ Figure A2.4 in the Appendix show the time path of levels and the first differences of budget shares, prices and real expenditure variables. To test for stationarity and orders of integrations in time-series data, the Dickey-Fuller (DF) is implemented. The results in

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model</th>
<th>t-statistic</th>
<th>Variable</th>
<th>Model</th>
<th>t-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>w1</td>
<td>τ</td>
<td>0.870</td>
<td>Δw1</td>
<td>τ</td>
<td>-15.754*</td>
</tr>
<tr>
<td>w2</td>
<td>τ</td>
<td>-0.683</td>
<td>Δw2</td>
<td>τ</td>
<td>-17.060*</td>
</tr>
<tr>
<td>w3</td>
<td>τ</td>
<td>0.400</td>
<td>Δw3</td>
<td>τ</td>
<td>-12.532*</td>
</tr>
<tr>
<td>w4</td>
<td>τ</td>
<td>-1.480</td>
<td>Δw4</td>
<td>τ</td>
<td>-19.545*</td>
</tr>
<tr>
<td>w5</td>
<td>τ</td>
<td>0.763</td>
<td>Δw5</td>
<td>τ</td>
<td>-11.933*</td>
</tr>
<tr>
<td>w6</td>
<td>τ</td>
<td>-0.550</td>
<td>Δw6</td>
<td>τ</td>
<td>-15.057*</td>
</tr>
<tr>
<td>w7</td>
<td>τ</td>
<td>-0.814</td>
<td>Δw7</td>
<td>τ</td>
<td>-12.654*</td>
</tr>
<tr>
<td>ln$p_1$</td>
<td>τ)$_\mu$</td>
<td>-1.058</td>
<td>Δln$p_1$</td>
<td>τ</td>
<td>-9.722*</td>
</tr>
<tr>
<td>ln$p_2$</td>
<td>τ</td>
<td>5.693</td>
<td>Δln$p_2$</td>
<td>τ</td>
<td>-6.590*</td>
</tr>
<tr>
<td>ln$p_3$</td>
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<td>5.418</td>
<td>Δln$p_3$</td>
<td>τ</td>
<td>-6.150*</td>
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<tr>
<td>ln$p_4$</td>
<td>τ</td>
<td>6.742</td>
<td>Δln$p_4$</td>
<td>τ</td>
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</tr>
<tr>
<td>ln$p_5$</td>
<td>τ</td>
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<td>Δln$p_5$</td>
<td>τ</td>
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</tr>
<tr>
<td>ln$p_6$</td>
<td>τ)$_\mu$</td>
<td>-1.752</td>
<td>Δln$p_6$</td>
<td>τ</td>
<td>-13.606*</td>
</tr>
<tr>
<td>ln$p_7$</td>
<td>τ</td>
<td>7.409</td>
<td>Δln$p_7$</td>
<td>τ</td>
<td>-9.131*</td>
</tr>
<tr>
<td>ln{$x/P$}</td>
<td>τ</td>
<td>1.206</td>
<td>Δln{$x/P$}</td>
<td>τ</td>
<td>-16.524*</td>
</tr>
</tbody>
</table>

\footnote{\textsuperscript{a} The unit root test is implemented by using the Dickey-Fuller (DF). Model τ indicates that no deterministic components are included. Model τ$_\mu$ indicates that only a constant is included.\textsuperscript{b} * denotes the rejection of the null hypothesis at the 5% level of significance.}
Table 2.1 indicate that we cannot reject the hypothesis that all variables are $I(1)$ at the 5% level of significance, which also shows first difference of the process will be stationary.

Seemingly unrelated regressions (SUR) estimation employing first differenced series is initially used to estimate parameters of the LA/AIDS model for the whole period from 1990.Q1 to 2013.Q2.\textsuperscript{28} Using Stone’s price index causes a simultaneity problem since the dependent variable $w_t$ appears on the right-hand side of the LA/AIDS.\textsuperscript{29} Therefore, this paper uses the lagged share for $P^*$, equal to $\log P^* = \sum_l w_{l,t-1} \log p_{l,t}$. Seasonal dummies and time dummy are included to capture seasonality and trend, although these coefficients aren’t reported. The adding-up restrictions in equation (2.9) are automatically satisfied, and one equation is dropped to meet the adding-up condition.\textsuperscript{30} The LA/AIDS was also estimated with homogeneity (i.e. $\sum_j y_{ij} = 0$) and symmetry (i.e. $y_{ij} = y_{ji}$) imposed.

Many empirical studies using LA/AIDS have rejected the restrictions, and researchers have been faced with a choice as to whether to proceed with a restricted and unrestricted version of the model.\textsuperscript{31} If the restrictions hypotheses are rejected, then the results might be open to criticism. However, as Li et al (2004) point out, simulation experiments in earlier studies have shown that restriction tests for homogeneity and symmetry have considerable bias toward rejection of the null hypothesis, especially when they are applied to a large demand system with

\textsuperscript{28} OLS applied to each equation yields a consistent estimator, but the FGLS estimator (SUR estimator) is more efficient when the errors are correlated across equations. The FGLS collapses to equation-by-equation OLS if the errors are uncorrelated across equations or if exactly the same regressors appear in each equation. This study uses SUR estimation despite the same regressors in each equation because separate equation-by-equation OLS gives less efficient standard errors of estimators. Another reason for using SUR estimation is that this paper is interested in imposing cross-equation parameter restrictions and testing joint hypothesis involving parameters in different equations. Since the sum of all expenditure shares in the LA/AIDS model is equal to unity, one equation from the system is deleted to estimate the remaining equations.

\textsuperscript{29} Adolf Buse (1994)

\textsuperscript{30} To apply SUR estimation, this study eliminates one equation, and estimates the model by systems estimation applied to the remaining 6 equations. Then, the parameter estimates for $i$th equation can be obtained using the adding-up constraint in equation (3). The estimates obtained are invariant to the equation eliminated; See A. Colin Cameron and Pravin K. Trivedi (2005), pp. 210.

\textsuperscript{31} Balcombe and Davis (1996), pp.54
Balcombe and Davis (1996) also showed that the results tended to indicate an over-rejection of hypotheses in finite samples when using the usual Wald test, and contended that the restrictions on the AIDS model should be treated as a maintained hypothesis. From this point of view, in this study, the homogeneity and symmetry restrictions are enforced directly in estimation according to the general properties of the demand theory.

The estimated coefficients are shown in Table A2.2 in the Appendix, and the test for homogeneity is given in the last row of Table A2.2. Symmetry, unlike homogeneity, cannot be tested on an equation-by-equation basis. The result of the Wald test for the symmetry restriction ($Y_{ij} = Y_{ji}$) on the demand system as a whole shows that symmetry is accepted for this model ($\chi^2 = 23.83$, p-value= 0.068) at a 10% significance level, while homogeneity is rejected for demand equations of telecommunications service (w1) and cultural services (w2).

Table 2.2 summarizes the elasticities of demand for telecommunications services calculated at the mean values of the budget shares during 1990.1Q-2013.2Q, which are obtained from the results of restricted SUR estimation. When the homogeneity and symmetry restrictions

| 1990.1Q-2013.2Q | Expenditure(income) | 0.23* |
| Cross-price | Telecommunications Services | -0.09* |
| Public transportation ($e_{12}^M$) | 0.07 |
| Cultural Services ($e_{13}^M$) | 0.04 |
| Books and other printed matter ($e_{14}^M$) | 0.06 |
| Private Education ($e_{15}^M$) | 0.57* |

NOTE: * represent significance level of 5%. The coefficient of real expenditure in demand equation for telecommunications is not significant, while most coefficients of prices variable are significant. For calculated elasticities to be significant, both coefficients of associated prices variables and real expenditure variable should be significant.

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32 Li, Song and Witt (2004), pp.143
were enforced in estimation, the expenditure (income) elasticity of demand for telecommunications services is less than 1, and demand is not sensitive to variations in own-price.

According to these results, households don’t seem to be sensitive to price and income variations. With respect to cross-price elasticities, public transportations, cultural services, books and other printed matter, and private education have substitution relationships with telecommunications services\(^{33}\), although all the cross-price elasticity values are not significant.

This analysis for the whole period from 1990.1Q to 2013.2Q has a limited ability to identify the structural changes in demand which resulted from the dramatic growth in telecommunications services during last two decades. Therefore, the analytical periods are divided into three segments according to the changes in budget shares as shown in Figure 2.1. The results of SUR estimation for each period are given in Table A2.3 in the Appendix. Table 2.3 and Table 2.4 provide elasticities of demand for telecommunications services over the period 1990.Q1-2013.Q2. The first analysis period represents the era of fixed voice service, and the second and third analysis periods represent the diffusion stage and the maturity stage of mobile and broadband services, respectively.

As shown in Table 2.3, the expenditure (income) elasticities are less than one over three periods, which means the demand for telecommunications services is not sensitive to variation in income. The income elasticity is very low in the era of fixed voice service, and it increases as advanced telecommunications such as mobile and broadband internet services are introduced. The own price elasticity for the period of 1990.Q1-1997.Q4 is not statistically significant. The absolute value of the own price elasticity noticeably increased in the period of 2005.4Q-2013.2Q,

\(^{33}\) The cross-price elasticities of demand for remaining categories aren’t reported.
Table 2.3 Changes in elasticities of demand for telecommunications services

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Expenditure (income) elasticity</td>
<td>0.05*</td>
<td>0.53*</td>
<td>0.39*</td>
</tr>
<tr>
<td>Own price elasticity</td>
<td>-0.81</td>
<td>-0.16*</td>
<td>-1.88*</td>
</tr>
</tbody>
</table>

* represent significance level of 5%.

and the reason might be that telecommunications services take up a higher proportion of household expenditure during this period. Also, this result might be attributable to the low and stable prices. During this period, operators are competitively offering better quality services with lower prices, and thus it seems that consumers’ demand become more responsive to even slight increases in prices.

The results in Table 2.4 show that mobile and internet services as multifunctional tools have been substitutes for public transportation, cultural services, books and other printed matter, and private education in household expenditure since 1997.4Q. The substitutability between telecommunications services and other goods/services since the introduction of the internet and mobile services reflects the substitution of offline for online activities. Cultural services, such as games, movie, music contents and broadcasting, have been complements since 2005.Q4, which means the spread of the internet leads to the expansion of online cultural services, and online cultural services and telecommunications services have been promoting each other. However, the cross-price elasticities in Table 2.4 should be interpreted with caution since most values are not significant at the 5% level.

34 This study will mainly focus on the period 1997.Q4-2013.Q2 since the changes in household expenditure patterns after telecommunications services advanced into multifunctional tools are more interesting.
Table 2.4 The effects of price change in telecommunications services on other expenditure

<table>
<thead>
<tr>
<th>Cross-price elasticities</th>
<th>1997.4Q-2005.4Q</th>
<th>2005.4Q-2013.2Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public transportation ($e^{M}_{12}$)</td>
<td>0.24</td>
<td>0.11</td>
</tr>
<tr>
<td>Cultural Services ($e^{M}_{13}$)</td>
<td>0.01</td>
<td>-0.05</td>
</tr>
<tr>
<td>Books and other printed matter ($e^{M}_{14}$)</td>
<td>0.13</td>
<td>0.50*</td>
</tr>
<tr>
<td>Private Education ($e^{M}_{15}$)</td>
<td>0.36</td>
<td>0.37</td>
</tr>
</tbody>
</table>

**NOTE:** *represent significance level of 5%. For the values to be significant, both the coefficients of associated prices variables and real expenditure variable should be significant.

2.4.2. Vector error correction LA/AIDS model for long-run relationship

The LA/AIDS estimation results in the previous section show only short-run relationship since they are estimated with a first differenced series to remove nonstationarity, resulting in loss of the long-run information from data. Hence, this paper employs a dynamic approach through a Vector Error Correction Model (VECM), and this approach is based on the idea that there exists a long-run equilibrium cointegrating demand system, which preserves the information about both the long-run relationship and short-run dynamics. In this approach, short-run dynamics implies the relationship between deviations of each variable from its long run trend, reflecting that the deviations from this equilibrium will be corrected over time.35 Estimation with nonstationary data series won’t cause a spurious regression problem as long as the variables in the regression are cointegrated, and an error correction model can be formulated.

Once the orders of integration of the variables have been identified, the test for the cointegration relationship can be employed. Two broad approaches for testing for cointegration have been developed. The Engle and Granger (1987) method is based on assessing whether

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35 William H. Green (2008), p.756
single-equation estimates of the equilibrium errors appear to be stationary. The second approach employing Johansen maximum likelihood approach (1991) is based on the VAR approach.\textsuperscript{36}

Many studies such as G.Karagiannis et al. (2000), Eakins and Gallagher (2003), and Li et al (2004) applied the Error Correction Model (ECM) LA/AIDS to their studies of demand for goods/services. In these studies, estimation of an ECM LA/AIDS are based on a single equation cointegration analysis using the Engle and Granger (1987) two-step procedure, and they test each equation separately for cointegration between one of budget shares and other regressors. However, this approach has critical drawbacks: firstly, it assumes there is only one cointegrating relationship between variables in each estimated equation. Secondly, the changes in prices and expenditure are assumed to be predetermined, so there can be no feedback from budget shares changes to prices or expenditure changes.

Therefore, to implement the dynamic model of LA/AIDS, this paper specifies a Vector Error Correction Model (VECM) as follows\textsuperscript{37}:

\[
\Delta Y_t = \mu D_t + \Gamma_1 \Delta Y_{t-1} + \cdots + \Gamma_{q-1} \Delta Y_{t-q+1} + \Pi Y_{t-1} + e_t
\]

where $Y_t$ is a column vector of budget shares (7 less one variables, which is arbitrarily deleted to avoid the singularity of the system), prices (7 variables) and real expenditure, $D_t$ is a vector of deterministic variables (intercept, trend, exogenous variables, etc.), $\mu$ is the matrix of parameters associated with $D_t$, $\Gamma_l$ are matrices of short-run parameters ($l = 1, \ldots, q-1$), with $q$ representing the number of lags, $\Pi$ is a matrix of long-run parameters and $e_t$ is the vector of disturbances, which follow identical and independent normal distributions with zero mean and $E(e_t e'_t) = \Sigma$. The number of cointegrating vectors is defined by the rank of the matrix $\Pi$. Therefore, the rank ($r$) of the matrix $\Pi$ must be less than 14. If rank ($\Pi$) = $r$, then $\Pi$ can be

\textsuperscript{36} See William H. Green (2008), p. 761
written as a product of \((14 \times r)\) matrix \(\alpha\) and \((r \times 14)\) matrix \(\beta'\) \((II = \alpha \beta')\). The parameters of \(\alpha\) represent the speed of adjustment towards the long run equilibrium after a shock, where \(\beta\) is a matrix of long-run coefficients such that the term \(\beta'Y_{t-1}\) represents the long run equilibrium. When \(r > 1\) the estimated coefficient matrix of \(\alpha\) and \(\beta\) are not necessarily uniquely determined. Therefore, the economic interpretation of cointegrating vectors as long run relationships requires the imposition of restrictions on cointegration space, and this study imposes symmetry and homogeneity restrictions based on a LA/AIDS model in addition to normalization conditions.\(^{38}\)

Before the estimation of Vector Error Correction Model (VECM), the lag order \((q)\), the deterministic components, and the cointegration rank \((k)\) need to be determined. Since the cointegrating relationship is confirmed, Vector Error Correction Model (VECM) can be established with 14 variables (6 budget shares, 7 prices and the real expenditure). On the basis of Schwarz information criterion (SC), a VECM estimation is carried out with just one lag \((q=1)\). Akaike information criterion (AIC) suggests 5 lags are optimal. However, due to small sample size, the most parsimonious model with one lag is chosen following the Schwarz information criterion (SC).\(^{39}\) Although the short-run dynamic characteristics of economic activities, \(\Gamma_{q-1}\) in equation (12), can’t be obtained with just one lag \((q=1)\), we can estimate cointegrating parameters as structural long run relationships. The model assumes variables have no deterministic trends and each cointegrating equation has an intercept.

To identify the cointegration rank, the Johansen restricted cointegration test is implemented, although it is normally expected to have \((n-1)\) cointegrating vectors when we have \(n\) budget shares, \(n\) prices and real expenditure.\(^{40}\) The results of a test suggest the presence of

\(^{38}\) Kaabia and Gil (2001), p.354 \\
\(^{39}\) M.Iooty et al (2009), p.5331 \\
\(^{40}\) M.Iooty et al (2009), p.5331
seven cointegrating relationships.\textsuperscript{41} Due to the small sample size, the significance of the adjustment coefficients for the 7\textsuperscript{th} cointegrating vector is tested as Juselius (1999) proposed. Since most of the estimated adjustment coefficients for the seventh cointegrating vector aren’t significant, implying seventh cointegrating relation in the model would not improve the explanatory power of the model, this paper will assume six cointegrating relations, which is consistent with the number of goods/services in the demand system.

As already implemented in the SUR estimation, the dynamic LA/AIDS model as VECM is also estimated separately on three different periods, and the data are seasonally adjusted. The results of these estimations show how household expenditure patterns changes as advanced telecommunications services market such as mobile and broadband expands.

Table A2.4 - A2.6 report the estimated $\beta$ matrices and the cointegrating vector from the restricted dynamic LA/AIDS model. Table 2.5 provides the results of elasticities of demand for telecommunications services based on the dynamic LA/AIDS for the whole period. In general, the long run elasticities from the VECM are greater than the elasticities from the short-run model.

<table>
<thead>
<tr>
<th>1990.1Q-2013.2Q</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Expenditure(income)</td>
<td>0.68*</td>
</tr>
<tr>
<td>Own-price</td>
<td></td>
</tr>
<tr>
<td>Telecommunications Services</td>
<td>-4.89*</td>
</tr>
<tr>
<td>Cross-price</td>
<td></td>
</tr>
<tr>
<td>Public transportation ($e_{12}^{M}$)</td>
<td>-1.63*</td>
</tr>
<tr>
<td>Cultural Services ($e_{13}^{M}$)</td>
<td>-0.55</td>
</tr>
<tr>
<td>Books and other printed matter ($e_{14}^{M}$)</td>
<td>0.60*</td>
</tr>
<tr>
<td>Private Education ($e_{15}^{M}$)</td>
<td>2.29*</td>
</tr>
</tbody>
</table>

\textit{NOTE:} * represent significance level of 5%.

\textsuperscript{41}The trace statistic as unrestricted cointegration rank test shows indicates 7 cointegrating relationships. (At maximum rank 7, trace statistic is 110.62 with 5% critical value 111.78.) In order to be consistent with economic theory, homogeneity and symmetry constraints are also imposed.Conditional on there being 6 cointegrating relationships, the LR test rejects the imposed restriction at 5%, while it accepts the hypothesis of 7 cointegrating relationships.
in terms of the absolute value, and this is reasonable since consumers’ choices are more flexible in response to prices and income changes in the long run equilibrium.

**Table 2.6 The long-run elasticities of demand for telecommunications services**

<table>
<thead>
<tr>
<th>Elasticties</th>
<th>1997Q4-2005.4Q</th>
<th>2005.4Q-2013.2Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expenditure (income) elasticity</td>
<td>0.91*</td>
<td>0.89*</td>
</tr>
<tr>
<td>Own price elasticity</td>
<td>-1.40</td>
<td>-1.89*</td>
</tr>
</tbody>
</table>

*NOTE: * represent significance level of 5%.

Table 2.6 provides elasticities of demand for telecommunications services for the diffusion stage and the maturity stage of new telecommunications services. Except for insignificant values, the overall results are similar to the results of the short-run model. The income elasticities of demand are less than one even after the introduction of mobile and internet services, and the absolute value of the price elasticity increases significantly as these services approach the maturity stage.

The results of the cross-price elasticities of demand for each period are reported in Table 2.7. Table 2.7 provides the effects of price changes in telecommunications services on expenditures on other goods/services items. Ever since mobile and internet service were firstly introduced in late 1997, books and other printed matter and private education have statistically significant substitution relationships with telecommunications, and these results are consistent

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42 To check whether the long-run cointegrating relationship remains sufficiently stable over time, the estimations with different time ranges were also implemented. For the maturity stage, the outcomes were stable with 9 years and 10 years of time frame, i.e., household demand for telecommunications was price elastic and income inelastic. Although the estimation results of the diffusion period were not stable when different time frames were applied, it is due to the exceptional expenditure change in 1998 when South Korea suffered serious economic crisis. As shown in Figure A2, household expenditure dropped sharply in 1998 (by 13%), and recovered the next year. Since expenditure pattern in 1998 was deviated from long-run trend, whether this year is included in analysis or not affected the outcomes significantly. However, when the estimations were applied on the time frames without 1998 provided stable results. Overall, the own price elasticities in the diffusion stage were less than those in maturity stage, and income elasticities were slightly greater than those in maturity stage.
with the values in Table 2.3 in the short-run model. Other values in this table don’t seem to be informative since some values are not statistically significant or not consistent with the results of the short-run model.

Table 2.7 The effects of price change in telecommunications services on other expenditures

<table>
<thead>
<tr>
<th>cross price elasticities</th>
<th>1997Q4-2005.4Q</th>
<th>2005.4Q-2013.2Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public transportation ($e_{12}^M$)</td>
<td>-0.39*</td>
<td>-0.05</td>
</tr>
<tr>
<td>Cultural Services ($e_{13}^M$)</td>
<td>0.21*</td>
<td>0.05</td>
</tr>
<tr>
<td>Books and other printed matter ($e_{14}^M$)</td>
<td>0.20*</td>
<td>0.36*</td>
</tr>
<tr>
<td>Private Education ($e_{15}^M$)</td>
<td>0.95*</td>
<td>2.06*</td>
</tr>
</tbody>
</table>

*NOTE: *represent significance level of 5%.

2.5. Conclusion

Using quarterly aggregate data from the household monthly expenditure in the Korean Statistical Information System (KOSIS), this study analyzed demand for telecommunications services and their relationships with other household expenditures. The linear approximate Almost Ideal Demand System (LA/AIDS) is implemented in both the short-run and long-run models. The main results can be summarized as follows.

Firstly, the household demand for telecommunications services in South Korea was income inelastic for the whole period, and both the short-run and the long-run models confirm this finding consistently. The income elasticity was the lowest in the era of fixed voice, and it increased after advanced telecommunications services such as mobile and broadband internet services were introduced. As these services approached the maturity stage since 2006, the income elasticity has slightly decreased.
Secondly, the own price elasticity of household demand has increased in the maturity stage. A higher proportion of household expenditure on telecommunications services might be the primary reason for high price elasticity of household demand. In the period of 1997.Q4-2005.Q4, household demand increased explosively, and the household budget shares for telecommunications services doubled from 3.1% to 6.4%. Since 2006, telecommunications services have taken up above 6% of total household expenditure, which might have made consumers’ demand more responsive to variations in prices. The higher price elasticity in the maturity stage might also be attributable to the low and stable prices. In the diffusion stage, the prices of mobile and broadband services decreased by 51.6% as a result of fierce price competition and the development of diverse price schedules. On the other hand, in the maturity stage, the price level decreased by 9.3% and price variations were relatively stable, which might be the reason why consumers became more sensitive to even slight changes in prices. This finding is worthy of notice in terms of policy implications. Government regulations to induce price-cutting might be no longer necessary in the maturity period of telecommunications services. Operators don’t have incentive to raise their prices since they may wind up losing the demand of consumers. Additionally, the policy focusing on price reductions may not be appropriate because it may paradoxically result in an increase in telecommunications expenditures, imposing a burden on household budgets, as Lee and Lee (2012) pointed out in their paper.

Thirdly, the estimations from the VECM LA/AIDS model suggest that telecommunications services have statistically significant long run relationships with other existing goods and services while, in the short run, most of those coefficients are not significant at the 5% level. During both the diffusion stage (1997.4Q - 2005.4Q) and the maturity stage
(2005.4Q – 2013.2Q) of mobile and broadband services, cultural services, books and other printed matter, and private education have had substitution relationships with telecommunications services. Mobile and internet services have substituted for cultural services such as movies, game software and music (DVD, CD, MP3 files, etc.). Online digital content such as books, newspapers, and a variety of learning materials provided by the internet has substituted for books and private education markets. On the other hand, public transportation has a complementary relationship with telecommunications services.

Although the estimations in this paper obtain reasonable results and those outcomes have interesting policy implications, the values in this study need to be interpreted cautiously due to the small observation size for each period. Additionally, considering heterogeneity across several household characteristics such as income levels and occupations, it can be studied how the relationships between telecommunications expenditures and other expenditures are different across the household groups.
## Appendix 2

### Table A2.1 Household expenditures

<table>
<thead>
<tr>
<th>Household expenditure</th>
<th>Item (i)</th>
<th>Component</th>
<th>Variable for a budget share for i</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Telecommunications</strong></td>
<td>Telecommunication services</td>
<td>Fixed/mobile telephone services, internet</td>
<td>$w_1$</td>
</tr>
<tr>
<td></td>
<td>Telecommunication equipment</td>
<td>Fixed/mobile telephone, other devices, and postal services</td>
<td></td>
</tr>
<tr>
<td><strong>Transportation</strong></td>
<td>Public transportation</td>
<td>Train, subway, taxi, airplane, etc.</td>
<td>$w_2$</td>
</tr>
<tr>
<td><strong>Culture and Recreation</strong></td>
<td>Cultural services</td>
<td>Concert, movie, contents (DVD, CD, MP3 files, game softwares, online contents), broadcasting</td>
<td>$w_3$</td>
</tr>
<tr>
<td></td>
<td>Books and other printed matter</td>
<td>Books, newspaper, magazine, etc.</td>
<td>$w_4$</td>
</tr>
<tr>
<td></td>
<td>Other Services and Durables for Recreation and Culture</td>
<td>Sport, fitness center, mountain climbing, fishing, sport supplies, sportwear</td>
<td>$w_6$</td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td>Private education</td>
<td>Private institutions and supplementary education</td>
<td>$w_5$</td>
</tr>
<tr>
<td><strong>Other miscellaneous goods/services</strong></td>
<td>Food, drinks, housing and utilities*, clothing, health, hotels, private transportation, public education, and miscellaneous others</td>
<td>Food, drinks, housing and utilities*, clothing, health, hotels, purchase of vehicles, maintenance of vehicles, cost of fuel, public education and miscellaneous others</td>
<td>$w_7$</td>
</tr>
</tbody>
</table>

*Note:* * Housing and Utilities category includes the actual monthly expenses for housing. It includes monthly rent, maintenance and repair of house, utilities and other services related to housing. The budget shares of this category are only 13%~15% because these data exclude the purchase costs of housing, mortgage interest payments, and or rental deposit (the so called ‘Chonsei’). Since there is a unique rental system in South Korea, which is called ‘Chonsei’, only a small portion of people pays monthly rents.
Table A2.2 SUR- Restricted Model (Homogeneous and symmetric) 1990.1Q-2013.2Q

<table>
<thead>
<tr>
<th>Commodity i</th>
<th>w1</th>
<th>w2</th>
<th>w3</th>
<th>w4</th>
<th>w5</th>
<th>w6</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_i$</td>
<td>-0.037*</td>
<td>-0.004</td>
<td>-0.004</td>
<td>-0.020</td>
<td>-0.024</td>
<td>0.020</td>
</tr>
<tr>
<td>ri1</td>
<td>0.042*</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
<td>0.025*</td>
<td>0.000</td>
</tr>
<tr>
<td>ri2</td>
<td>0.002</td>
<td>-0.011</td>
<td>-0.004</td>
<td>0.024*</td>
<td>0.009</td>
<td>-0.009*</td>
</tr>
<tr>
<td>ri3</td>
<td>0.002</td>
<td>-0.004</td>
<td>0.001</td>
<td>0.000</td>
<td>-0.004</td>
<td>0.002</td>
</tr>
<tr>
<td>ri4</td>
<td>0.002</td>
<td>0.024*</td>
<td>0.000</td>
<td>0.023*</td>
<td>-0.004</td>
<td>0.009*</td>
</tr>
<tr>
<td>ri5</td>
<td>0.025</td>
<td>0.009</td>
<td>-0.004</td>
<td>-0.004</td>
<td>0.035</td>
<td>0.007</td>
</tr>
<tr>
<td>ri6</td>
<td>0.000</td>
<td>-0.009</td>
<td>0.002</td>
<td>0.009*</td>
<td>0.007</td>
<td>0.009</td>
</tr>
<tr>
<td>ri7</td>
<td>-0.073*</td>
<td>-0.011</td>
<td>0.002</td>
<td>-0.054*</td>
<td>-0.068*</td>
<td>-0.018</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.727</td>
<td>0.651</td>
<td>0.627</td>
<td>0.888</td>
<td>0.611</td>
<td>0.503</td>
</tr>
</tbody>
</table>

Test for Homogeneity
$F(1,81)$
9.367* 6.449* 0.267 0.549 1.921 0.972

* represent significance level of 5%

Table A2.3 SUR- Restricted parameter estimates (Periods classification)

1990.1Q-1997.4Q

<table>
<thead>
<tr>
<th>Commodity i</th>
<th>w1</th>
<th>w2</th>
<th>w3</th>
<th>w4</th>
<th>w5</th>
<th>w6</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_i$</td>
<td>-0.022*</td>
<td>-0.028*</td>
<td>-0.004</td>
<td>-0.012*</td>
<td>-0.021</td>
<td>0.037</td>
</tr>
<tr>
<td>ri1</td>
<td>0.004</td>
<td>-0.002</td>
<td>0.005</td>
<td>-0.007</td>
<td>0.018</td>
<td>0.001</td>
</tr>
<tr>
<td>ri2</td>
<td>-0.002</td>
<td>-0.009</td>
<td>-0.006</td>
<td>0.009</td>
<td>-0.014</td>
<td>-0.005</td>
</tr>
<tr>
<td>ri3</td>
<td>0.005</td>
<td>-0.006</td>
<td>-0.014</td>
<td>0.002</td>
<td>-0.005</td>
<td>0.004</td>
</tr>
<tr>
<td>ri4</td>
<td>-0.007</td>
<td>0.009*</td>
<td>0.002</td>
<td>0.020*</td>
<td>-0.001</td>
<td>0.008*</td>
</tr>
<tr>
<td>ri5</td>
<td>0.018</td>
<td>-0.014</td>
<td>-0.005</td>
<td>-0.001</td>
<td>-0.014</td>
<td>0.022*</td>
</tr>
<tr>
<td>ri6</td>
<td>0.001</td>
<td>-0.005</td>
<td>0.004</td>
<td>0.008*</td>
<td>0.022*</td>
<td>0.025*</td>
</tr>
<tr>
<td>ri7</td>
<td>-0.020</td>
<td>0.028</td>
<td>0.013</td>
<td>-0.030*</td>
<td>-0.006</td>
<td>-0.055*</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.827</td>
<td>0.500</td>
<td>0.667</td>
<td>0.976</td>
<td>0.665</td>
<td>0.766</td>
</tr>
</tbody>
</table>

1997.4Q-2005.4Q

<table>
<thead>
<tr>
<th>Commodity i</th>
<th>w1</th>
<th>w2</th>
<th>w3</th>
<th>w4</th>
<th>w5</th>
<th>w6</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_i$</td>
<td>-0.028*</td>
<td>0.020*</td>
<td>-0.001</td>
<td>-0.023*</td>
<td>-0.012</td>
<td>0.041*</td>
</tr>
<tr>
<td>ri1</td>
<td>0.048*</td>
<td>0.013</td>
<td>0.000</td>
<td>0.007</td>
<td>0.019</td>
<td>-0.001</td>
</tr>
<tr>
<td>ri2</td>
<td>0.013</td>
<td>-0.003</td>
<td>-0.002</td>
<td>0.008</td>
<td>0.006</td>
<td>-0.009</td>
</tr>
<tr>
<td>ri3</td>
<td>0.000</td>
<td>-0.002</td>
<td>0.016</td>
<td>-0.003</td>
<td>-0.012</td>
<td>-0.001</td>
</tr>
<tr>
<td>ri4</td>
<td>0.007</td>
<td>0.008</td>
<td>-0.003</td>
<td>0.040*</td>
<td>-0.055*</td>
<td>0.013</td>
</tr>
<tr>
<td>Commodity</td>
<td>w1</td>
<td>w2</td>
<td>w3</td>
<td>w4</td>
<td>w5</td>
<td>w6</td>
</tr>
<tr>
<td>-----------</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>βi</td>
<td>-0.037*</td>
<td>-0.026*</td>
<td>-0.003</td>
<td>-0.013*</td>
<td>0.015</td>
<td>0.011</td>
</tr>
<tr>
<td>ri1</td>
<td>-0.058*</td>
<td>0.006</td>
<td>-0.004</td>
<td>0.031*</td>
<td>0.020</td>
<td>0.005</td>
</tr>
<tr>
<td>ri2</td>
<td>0.006</td>
<td>0.020*</td>
<td>0.001</td>
<td>0.023*</td>
<td>0.001</td>
<td>-0.009</td>
</tr>
<tr>
<td>ri3</td>
<td>-0.004</td>
<td>0.001</td>
<td>0.022</td>
<td>0.015</td>
<td>-0.079*</td>
<td>0.002</td>
</tr>
<tr>
<td>ri4</td>
<td>0.031*</td>
<td>0.023*</td>
<td>0.015</td>
<td>-0.024</td>
<td>-0.056*</td>
<td>0.005</td>
</tr>
<tr>
<td>ri5</td>
<td>0.020</td>
<td>0.001</td>
<td>-0.079*</td>
<td>-0.056*</td>
<td>-0.045</td>
<td>0.007</td>
</tr>
<tr>
<td>ri6</td>
<td>0.005</td>
<td>-0.009</td>
<td>0.002</td>
<td>0.005</td>
<td>0.007</td>
<td>0.015</td>
</tr>
<tr>
<td>ri7</td>
<td>-0.001</td>
<td>-0.042*</td>
<td>0.042*</td>
<td>0.006</td>
<td>0.153*</td>
<td>-0.025</td>
</tr>
<tr>
<td>R²</td>
<td>0.958</td>
<td>0.953</td>
<td>0.664</td>
<td>0.946</td>
<td>0.844</td>
<td>0.651</td>
</tr>
</tbody>
</table>

Table A2.4 Estimated cointegrating vectors under long run structural identification: ‘90.Q1-‘97.Q4

<table>
<thead>
<tr>
<th>w1</th>
<th>w2</th>
<th>w3</th>
<th>w4</th>
<th>w5</th>
<th>w6</th>
<th>lnp1</th>
<th>lnp2</th>
<th>lnp3</th>
<th>lnp4</th>
<th>lnp5</th>
<th>lnp6</th>
<th>lnp7</th>
<th>ln(X/P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>β'₁</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-0.073</td>
<td>0.016</td>
<td>-0.001</td>
<td>0.013</td>
<td>-0.031</td>
<td>0.085</td>
<td>-0.010</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.012)</td>
<td>(0.009)</td>
<td>(0.003)</td>
<td>(0.005)</td>
<td>(0.011)</td>
<td>(0.008)</td>
<td>(0.028)</td>
</tr>
<tr>
<td>β'₂</td>
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<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.016</td>
<td>0.032</td>
<td>0.015</td>
<td>-0.016</td>
<td>0.034</td>
<td>0.052</td>
<td>-0.134</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td>(0.009)</td>
<td>(0.009)</td>
<td>(0.002)</td>
<td>(0.004)</td>
<td>(0.010)</td>
<td>(0.007)</td>
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</tr>
<tr>
<td>β'₃</td>
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<td>-0.001</td>
<td>0.015</td>
<td>-0.073</td>
<td>-0.006</td>
<td>0.046</td>
<td>0.045</td>
<td>-0.026</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.003)</td>
<td>(0.002)</td>
<td>(0.006)</td>
<td>(0.002)</td>
<td>(0.005)</td>
<td>(0.002)</td>
<td>(0.009)</td>
</tr>
<tr>
<td>β'₄</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0.013</td>
<td>-0.016</td>
<td>-0.006</td>
<td>-0.002</td>
<td>-0.010</td>
<td>-0.044</td>
<td>0.066</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>(0.005)</td>
<td>(0.004)</td>
<td>(0.002)</td>
<td>(0.003)</td>
<td>(0.006)</td>
<td>(0.003)</td>
<td>(0.014)</td>
</tr>
<tr>
<td>β'₅</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>-0.031</td>
<td>0.034</td>
<td>0.046</td>
<td>-0.010</td>
<td>0.049</td>
<td>0.117</td>
<td>-0.205</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>(0.011)</td>
<td>(0.010)</td>
<td>(0.005)</td>
<td>(0.006)</td>
<td>(0.020)</td>
<td>(0.009)</td>
<td>(0.037)</td>
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<tr>
<td>β'₆</td>
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<td>0</td>
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<td>1</td>
<td>0.085</td>
<td>0.052</td>
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<td>-0.044</td>
<td>0.117</td>
<td>0.022</td>
<td>-0.276</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.008)</td>
<td>(0.007)</td>
<td>(0.002)</td>
<td>(0.003)</td>
<td>(0.009)</td>
<td>(0.009)</td>
<td>(0.023)</td>
</tr>
<tr>
<td></td>
<td>w1</td>
<td>w2</td>
<td>w3</td>
<td>w4</td>
<td>w5</td>
<td>w6</td>
<td>lnp1</td>
<td>lnp2</td>
<td>lnp3</td>
<td>lnp4</td>
<td>lnp5</td>
<td>lnp6</td>
<td>lnp7</td>
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<td>------</td>
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<td>------</td>
</tr>
<tr>
<td>$\beta'_1$</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-0.024</td>
<td>-0.024</td>
<td>0.013</td>
<td>0.012</td>
<td>0.056</td>
<td>-0.024</td>
<td>-0.009</td>
</tr>
<tr>
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Table A2.5 Estimated cointegrating vectors under long run structural identification: ‘97.Q4–‘05.Q4

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Table A2.6 Estimated cointegrating vectors under long run structural identification: ‘05.Q4–‘13.Q2
Figure A2.1 Time plots in levels of budget shares
Figure A2.2 Time plots in levels of prices and real expenditure
Figure A2.3 Time plots in differences of budget shares
Figure A2.4 Time plots in differences of prices and real expenditure
Chapter 3

Three-Part Tariffs in Monopoly and Homogeneous-Product Duopoly

3.1. Introduction

Nonlinear pricing has been used in many industries as a means of price discrimination that allows a firm with market power to increase its profit or as a marketing practice which is motivated by competitive pressures in competitive markets. Among a variety of usage based nonlinear pricing schemes, the three-part tariff is one of the popular schemes, which consists of a fixed access fee, an allowance of usage for that fixed fee (or a usage cap) and a per unit price (or marginal price) for additional usage beyond the allowance.

Three-part tariffs have become the most prevalent pricing scheme especially in the telecommunications industry. Telecommunications services, such as fixed and mobile voice service and Internet service, have a limited scope for differentiating the service offering. Therefore, menus of three-part tariffs have been designed as a marketing strategy to attract consumers by differentiating consumer types according to their usage. Additionally, the explosive growth in demand for Internet services and mobile services adds to the burden of firms’ investment in networks, and firms in this industry started to reconsider the flat-rate tariff that has been used for the last two decades, moving to usage based three-part tariff pricing schemes. A variety of three-part tariffs is observed in practice: AT&T, U.S Internet service provider, offers residential High Speed Internet service, charging consumers $34.95 per month for 250 gigabytes (GB) of usage and $10 for every incremental 50 GB beyond the allowance. A
typical three-part tariff plan that will be examined in this study is most common in local and international calling services. For instance, Verizon offers 300 minutes of direct-dialed calling to wireline and wireless phones in international destinations, charging $14.99 per month and additional per minute rates for usage beyond the allowance.

Despite the widespread use of three-part tariffs, the study of such tariffs from a theoretical perspective has received less attention. The extensive economic literature on multi-part tariffs has mostly focused on two-part tariffs, a pricing scheme consisting of a fixed access fee and a constant marginal price. Moreover, the work on two-part tariffs in a competitive setting has been more limited than in the context of a monopoly market.

In a monopoly context, Oi (1971) is a classic study on the two-part tariff. Oi showed that a two-part tariff with homogeneous consumers can be more efficient than a uniform price in extracting consumer surplus, with a fixed fee charged and marginal price set equal to marginal cost. With two types of consumers, Oi showed that profits can be increased by raising price above marginal cost in all but exceptional cases. Sundararajan (2004) showed that offering the combination of fixed fee pricing and nonlinear usage-based pricing is always profit improving in the presence of a positive transaction cost, and there may be markets in which a pure fixed fee is optimal. Bagh and Bhargava (2013) is a recent study on three-part tariffs in a monopoly context. They showed a relatively small menu of three-part tariffs is more profitable than a menu of two-part tariffs. However, despite the interesting aspects, these studies didn’t characterize the optimal three-part tariff and restricted their attention to the monopoly case.

Harrison and Kline (2001) extended the two-part tariff analysis of Oi (1971) to the oligopoly case. Harrison and Kline offered a traditional Cournot competition model with identical consumers, and found that, in equilibrium, marginal price is equal to marginal cost, and
that the fixed fee is positive for a given number of firms, but it approaches zero as the number of firms becomes large. Extending Harrison and Kline (2001), Jensen and Sørgard (2005) showed firms’ two-part tariff strategies may change when consumer heterogeneity is allowed. They found that if both types of consumers are served, the price per unit may be either above or below marginal cost, and that the fixed fee may be positive even with an infinite number of firms. These studies assume Cournot competition, where each firm commits to a quantity and a fixed fee prior to the determination of unit price.

However, when analyzing the three-part tariffs observed in the information industry, a Bertrand competition model may be more plausible since firms compete in terms of prices rather than quantities. Yin (2004) study two-part tariffs in terms of Bertrand competition. Yin showed that two-part tariffs tend to result in lower prices, higher profits and social welfare relative to uniform pricing, using the assumption of differentiated product competition. Lambrecht et al. (2007) studied three-part tariff Bertrand competition. Lambrecht et al. focused on consumers’ tariff and usage-quantity choice decisions under three-part tariffs. They found that consumers choose tariffs with high allowances since their expected bill increases with the variation in their usage, which implies that demand uncertainty decreases consumer surplus. However, Lambrecht et al. (2007) took specific three-part tariffs as given for all firms, and as a result, the optimality of three-part tariffs from a firm’s perspective and the corresponding competitive effects of competing firms were not considered in their article. Chao (2013) is the most recent paper studying three-part tariffs. However, his paper analyzed anti-competitive effects of quantity thresholds in three-part tariffs on the following firm, which is not the issue in this study.

The purpose of this paper is to characterize the optimal three-part tariff plans in both monopoly and duopoly cases and to show how the market is segmented in equilibrium when full
market coverage is assumed. In the first part of this study, the three-part tariff strategy of a monopoly will be characterized. It turns out that a profit maximizing monopoly with two types of consumers will set its marginal price above marginal cost, and set its usage cap above the low type consumers’ optimal usage at the marginal price.

To analyze the optimal three-part tariff in duopoly, this study will formulate a homogeneous product competition model instead of assuming differentiated product competition. In other words, we assume a price competition situation in the telecommunications industry where consumers choose a firm by comparing, for instance, the Internet plan of AT&T with 6Mbps speed with the Internet plan of Comcast with a similar speed, not with 30Mbps plan of Comcast. Our duopoly results show the simple Bertrand competition logic, that is, price competition between identical firms leads to pricing at cost and zero profits, can apply to the case of three-part tariff. It can be expected that there might exist asymmetric price equilibria with heterogeneous users, with firms earning positive profits by taking advantage of more flexibility in pricing scheme. In this study, however, it is found that asymmetric equilibria do not exist, and only a symmetric three-part tariff equilibrium where both firms will share both types of consumers can be achieved as an equilibrium, with a standard Bertrand outcome still holding.

This study is organized as follows. In Section 3.2, notation and definitions are presented. Section 3.3 formulates the model using the monopoly case and characterizes the outcome in the present of heterogeneous users. Section 3.4 explores the possibility that any of symmetric and asymmetric pricing strategies can be equilibria in duopoly and describes the optimal feature of the tariffs. Section 3.5 concludes with some implications of this analysis.

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43 This assumption is reasonable since, in most countries, a regulator of the telecommunications industry aims at promoting the availability of telecommunications services throughout the country at reasonable rates. In particular, the firms offering fixed voice services are subject to the ‘Universal Service Obligation’, which is a regulatory mandate to serve all consumers.

44 The Internet plan of 6Mbps means you can download 6Megabits of data per second through the Internet.
3.2. The model and heterogeneous consumers

Consider a service provider that sells telecommunications services to two types of consumers. We will refer to the first group as low demand consumers or type \( L \), and the other group as high demand consumers or type \( H \). Consumers are assumed to have quasi-linear utility functions, \( w(t, \theta) \), with \( t \) representing data usage (or call usage) and \( \theta \) being a shift parameter that takes different values for the two groups, \( \theta_H \) and \( \theta_L < \theta_H \). In addition, assume that \( \partial w / \partial \theta > 0 \) holds for \( t > 0 \). It is natural to assume that \( w(0, \theta_L) = w(0, \theta_H) = 0 \).

The maximized value of utility is

\[
v(\theta_i) \equiv \max_t \{ w(t, \theta_i) + y - \max\{0, t - \bar{t}\} p - K \}, \quad i = L, H
\]  

(3.1)

where \( y \) is the common level of income for the two types, \( \bar{t} \) is the usage cap, and \( K \) is a lump sum fee which users pay when they subscribe to Internet, allowing full usage up to the cap, and \( p \) is per-unit price for additional data usage beyond that usage cap \( \bar{t} \). Thus, \( \max\{0, t - \bar{t}\} p + K \) is the consumer’s outlay for the service. By the envelope theorem, \( v'(\theta) = \partial w(t^*(\theta), \theta) / \partial \theta > 0 \), where \( t^*(\theta) \) is the optimal value of \( t \). Therefore, type \( H \), which has the higher \( \theta \), has the higher maximum value of utility.

Let \( u_i(t) \equiv w(t, \theta_i) \) for \( i = H, L \), with \( u_H(t) > u_L(t) \), \( u'_H(t) > u'_L(t) > 0 \), \( u''_L(t) < 0 \) holding for \( t > 0 \). Since \( v(\theta_i) \) is increasing in \( t \) when \( t < \bar{t} \), the optimal consumption level \( t^*(\theta) \) satisfies \( t^*(\theta_i) \geq \bar{t} \) for \( i = H, L \). Then, letting \( t^*_i \) denote \( t^*(\theta_i) \), and the conditions for choice of \( t^*_i \) for \( i = H, L \), are

\[
t^*_i = \bar{t} \quad \text{if} \quad u'_i(\bar{t}) \leq p
\]

and

\[
t^*_i \quad \text{satisfies} \quad u'_i(t^*_i) = p \quad \text{otherwise.} \]  

(3.2)
Let $D_i(p) \equiv u_i^{i-1}(p)$ denote the demand functions for the two types, $i = H, L$. Then, given the properties of the $u$ functions, the demand functions are downward sloping and $D_H(p) > D_L(p)$ holds. Using the demand functions, (3.2) can be rewritten as

$$
t_i^* = \bar{t} \quad \text{if} \quad D_i(p) \leq \bar{t},
$$

$$
t_i^* = D_i(p) \quad \text{if} \quad D_i(p) > \bar{t}.
$$

(3.3)

Throughout this paper, we assume that each consumer will use the full amount of allowed usage, without loss of generality.

### 3.3. Monopoly case

This section considers the case of a monopoly offering a three-part tariff. It is assumed that firms can meet the demand instantly, i.e., no capacity constraint, and that the market is fully covered. The cost function is characterized by constant returns to scale, $c(T) = \beta T$, where $\beta > 0$ is the marginal cost and $T$ is total usage by the two types of consumers. For simplicity, fixed costs are omitted. The number of consumers for each group is represented by $n_i$ for $i = H, L$.

The participation constraints for consumers are

$$
u_i(t_i^*) + y - \max(0, t_i^* - \bar{t}) p - K \geq y, \quad \text{for} \ i = L, H
$$

(3.4)

where $y$ is the utility level achieved with no purchase of this service. Since (3.4) can be rewritten as $\nu(\theta_i) \geq y$ and $\nu(\theta_H) > \nu(\theta_L)$ holds as explained in Section 3.2, it follows that $\nu(\theta_L) \geq y$ implies satisfaction of both participation constraints in (3.4). In other words, if the

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45 Depending on the willingness to pay, it might be beneficial for a monopoly to exclude the low demand type. However, in this study, we assume that all consumers are served.
low demand type finds it rational to participate, then both types will participate. Therefore, using (3.3) and (3.4), the relevant constraint of a monopoly can be written as

\[ u_L(\max\{D_L(p), \bar{\bar{c}}\}) - \max\{0, (D_L(p) - \bar{\bar{c}})\} p - K \geq 0. \]  

(3.5)

Now, considering the profit maximization problem of the monopoly carrier, the following proposition is obtained:

**Proposition 1**

*When a monopoly firm facing two types of users sets \( \bar{\bar{c}} \) and \( p \), the optimal per unit price is above marginal cost \( p > \beta \) and \( D_L(p) < \bar{\bar{c}} < D_H(p) \), so that the usage cap lies above the level demanded by type L consumers at price \( p \). The optimal lump sum fee \( K \) will be raised to the point where the consumer type with the smaller willingness to pay is fully exploited, so that \( K = u_L(\bar{E}) \).*

To prove the proposition, the following three cases need to be checked to see cases can be achieved as equilibria.

**Case (I) \( \bar{\bar{c}} \leq D_L(p) < D_H(p) \)**

First, consider the pricing strategy where both types of consumers pay lump sum fees and overage charges. In this case, the profit maximization problem of a monopoly carrier is given by

\[
\max_{\{k, L, p\}} (n_L + n_H)K + n_Lp(D_L(p) - \bar{\bar{c}}) + n_Hp(D_H(p) - \bar{\bar{c}}) - \beta(n_LD_L(p) + n_HD_H(p)) \\
\text{s.t. } u_L(D_L(p)) - p(D_L(p) - \bar{\bar{c}}) - K \geq 0.
\]

Letting \( \lambda \) denote the Lagrangian multiplier for the participation constraints, the first order conditions are given by

\[ K: (n_L + n_H) - \lambda = 0, \]  

(3.6)
\[ p: \quad n_L(p - \beta)D'_L(p) + n_H(p - \beta)D'_H(p) + n_L(D_L(p) - \bar{\epsilon}) + n_H(D_H(p) - \bar{\epsilon}) + \lambda (-D_L(p) + \bar{\epsilon}) = 0, \quad (3.7) \]

\[ \bar{\epsilon}: \quad -(n_L + n_H)p + \lambda p = 0, \quad (3.8) \]

\[ \lambda (u_L(D_L(p)) - p(D_L(p) - \bar{\epsilon}) - K) = 0, \quad \text{and} \]

\[ \lambda \geq 0, \quad u_L(D_L(p)) - p(D_L(p) - \bar{\epsilon}) - K \geq 0 \]

The condition (3.7) can be rewritten as

\[ n_L(p - \beta)D'_L(p) + n_H(p - \beta)D'_H(p) + n_LD_L(p) + n_HD_H(p) - (n_L + n_H)D_L(p) \]

\[ = (p - \beta)[n_LD'_L(p) + n_HD'_H(p)] + n_H(D_H(p) - D_L(p)) = 0. \quad (3.10) \]

From (3.10), \( p > \beta \) should hold from \( D'_L(p) < 0 \) and \( D'_H(p) > D_L(p) \). From equation (3.6) and (3.8), the partial derivative with respect to \( \bar{\epsilon} \) shows that the changes in \( \bar{\epsilon} \) don’t affect profit. Also, the partial derivative with respect to \( p \), equation (3.10), shows that the optimal \( p \) is independent of \( \bar{\epsilon} \) when \( D_H(p) \) and \( D_L(p) \) are not less than the usage cap \( \bar{\epsilon} \). Therefore, \( \bar{\epsilon} \) can be set initially such that \( D_L(p) = \bar{\epsilon} < D_H(p) \).

Suppose that a monopoly carrier increases \( \bar{\epsilon} \) to the point where \( \bar{\epsilon} = D_L(p) \). Then, the profit of this firm is

\[ \pi = n_Hp(D_H(p) - \bar{\epsilon}) + (n_L + n_H)u_L(\bar{\epsilon}) - \beta (n_HD_H(p) + n_L\bar{\epsilon}), \]

and the partial derivative with respect to \( \bar{\epsilon} \), \( \partial \pi / \partial \bar{\epsilon} \), is

\[ \frac{\partial \pi}{\partial \bar{\epsilon}} = -n_Hp + (n_H + n_L)u'_L(\bar{\epsilon}) - \beta n_L. \]

\[ ^{46} \text{Since } \lambda > 0, \text{ the constraint is binding, } K = u_L(\bar{\epsilon}) \text{ must hold in the case of } \bar{\epsilon} = D_L(p). \]
Figure 3.1. The effects of changes in $\bar{t}$ on profits

The sign of $\partial \pi / \partial \bar{t}$ evaluated at $\bar{t} = D_L(p)$ is positive since $u'_L(\bar{t}) = p$ and $p > \beta$ as shown in Figure 3.1. In the case of $\bar{t} \leq D_L(p) < D_H(p)$, a monopoly firm has an incentive to raise $\bar{t}$ enough so that type $L$ doesn’t buy additional units above the usage cap, so that $\bar{t}$ lies above the level demanded by type $L$ consumers at price $p$. Hence, this case can’t be admissible as a possible equilibrium.

**Case (II) $D_L(p) < \bar{t} < D_H(p)$**

Consider the case where only type $H$ pays overage charges, i.e., $t_H^* = \bar{t} < t_H^*$ from (3.3).

In this case, the maximization problem is given by

$$\max_{(K, \bar{t}, p)} n_H p (D_H(p) - \bar{t}) + (n_L + n_H) K - \beta (n_H D_H(p) + n_L \bar{t})$$

s.t. $u_L(\bar{t}) \geq K$.

Letting $\lambda$ denote the Lagrangian multiplier for the participation constraints, the first order conditions are given by

$$K : (n_L + n_H) - \lambda = 0 \quad (3.11)$$
\[ \tilde{\ell} : -n_H p - \beta n_L + \lambda u_L'(\ell) = 0 \quad (3.12) \]

\[ p : (p - \beta)D_H'(p) + D_H(p) - \tilde{\ell} = 0 \quad (3.13) \]

\[ \lambda(u_L(\ell) - K) = 0, \text{ and } \lambda \geq 0, \quad u_L(\ell) - K \geq 0. \quad (3.14) \]

Since \( D_H(p) > \tilde{\ell} \), the condition \( p > \beta \) should hold from (3.13).\(^{47} \) Then, equations (3.11) and (3.12) yield

\[ u_L'(\ell) = \frac{n_H p + \beta n_L}{n_H + n_L}, \quad (3.15) \]

Note that \( p > \beta \) implies

\[ \beta < \frac{n_H p + \beta n_L}{n_H + n_L} < p, \]

so that \( \beta < u_L'(\ell) < p \).

Therefore, the Case (II) can be admissible as a possible solution. The optimal values of \( p \) and \( \ell \) can be obtained by solving (3.13) and (3.15). The optimal \( K \) is given by \( K = u_L(\ell) \), extracting all the surplus of type \( L \) consumers. The optimal per unit price is above marginal cost, and optimal usage cap satisfies \( D_L(p) < \tilde{\ell} < D_L(\beta) \). At the optimal allowance level, the low-demand type’s marginal utility is less than the marginal price, and greater than marginal cost. This result implies that the monopoly firm raises the allowance level higher than the actual demand of type \( L \) consumers at the optimal marginal price, so that it could maximize the profits from the lump sum fee. The type \( H \) group consumes above the allowance level, although both types’ consumption levels are still low from a social viewpoint.

\(^{47} \) Although \( p = \beta \) and \( D_H(p) = \tilde{\ell} \) satisfies equation (3.13), this case can be ruled out. If \( p = \beta \), then \( u_L'(\ell) = p \), i.e., \( D_L(p) = \tilde{\ell} \) should hold from equation (3.12), which is a contradiction given \( u_H > u_L \).
Case (III) $D_L(p) < D_H(p) \leq \bar{t}$

Lastly, consider the case where per unit price $p$ is so high so that neither group pays overage charges. In this case, the maximization problem is given by

$$
\max_{\{K, \bar{t}\}} (n_L + n_H)K - \beta (n_L \bar{t} + n_H \bar{t})
$$

$$
s.t. \ u_L(\bar{t}) \geq K.
$$

Letting $\lambda$ denote the Lagrangian multiplier for the participation constraints, the first order conditions are given by

$$
K : (n_L + n_H) - \lambda = 0 \quad (3.16)
$$

$$
\bar{t} : -\beta (n_L + n_H) + \lambda u'_L(\bar{t}) = 0 \quad (3.17)
$$

$$
\lambda(u'_L(\bar{t}) - K) = 0, \text{ and } \lambda \geq 0, \ u_L(\bar{t}) - K \geq 0 \quad (3.18)
$$

From (3.16) – (3.18), it is obtained that $u'_L(\bar{t}) = \beta$. Given the assumption $u'_H(\bar{t}) > u'_L(\bar{t})$, there exists a price $\hat{p}$ satisfying the condition $u'_L(\bar{t}) = \beta < \hat{p} < u'_H(\bar{t})$. Thus, a monopoly firm can increase its profit by decreasing the price to $\hat{p}$, where the optimal usage of type $H, t_H^*$, is above $\bar{t}$.

This condition rules out this case as a possible solution to the profit maximizing problem.

To summarize, in a monopoly case where both types of consumers are served, a firm’s optimal three-part tariff is determined jointly by the conditions

$$
(p - \beta)D'_H(p) + D_H(p) - \bar{t} = 0, \quad u'_L(\bar{t}) = \frac{n_H p + \beta n_L}{n_H + n_L}, \quad K = u_L(\bar{t}). \quad (3.19)
$$

Thus, at the optimum, a three-part tariff and consumers’ usages are as follows:

$$
p > \beta, \quad D_L(p) < \bar{t} < D_L(\beta), \quad K = u_L(\bar{t})
$$

$$
t^*_L = \bar{t}, \quad t^*_H > \bar{t}. \quad (3.20)
$$
3.4. Three-part tariff competition in a homogeneous product duopoly

This section describes the case where two firms, denoted by firm 1 and firm 2, offer a homogeneous product to the two types of consumers. The number of \(i\)-type consumers using firm \(j\) is denoted by \(n_{ji}\) for \(i = L, H\) and \(j = 1, 2\).

To illustrate the equilibrium outcomes, this study considers both symmetric and asymmetric equilibrium candidates, as follows: \textit{Case (A)} Firms have symmetric price strategies and share both types of consumers, \textit{Case (B)} Firm 1 serves only consumer type \(L\) and firm 2 serves only consumer type \(H\), \textit{Case (C)} Firm 1 serves both type \(L\) and type \(H\) and firm 2 serves type \(H\), and \textit{Case (D)} Firm 1 serves only type \(L\) and firm 2 serves both type \(L\) and type \(H\).

Since consumers differ with respect to their usage levels, there might exist asymmetric equilibria if the elements of prices for two firms are set at the different levels from each other. However, it turns out that \textit{Case (A)} is the only equilibrium in the four possible cases above, so that asymmetric equilibria don’t exist. The symmetric equilibrium of \textit{Case (A)} is described as follows, and the proofs of nonexistence of asymmetric equilibria are given in Appendix.

\textit{Proposition 2}

\textit{There is a symmetric duopoly competition equilibrium where both firms share both types of consumers and earn zero profits. Per unit price is equal to marginal cost, and the usage cap is set equal to the low demand consumer’s optimal usage at the per unit price, so only high demand consumers pay overage charges. The lump sum fee equals the cost of serving that low demand consumer.}

\[ p = \beta, \quad D_L(p) = \bar{\epsilon}, \quad K = \beta \bar{\epsilon}. \]  

(3.21)

Consider the case where both types are served by both firms adopting symmetric three-part tariffs where both firms initially set \(\bar{\epsilon}\) such that \(D_L(p) \leq \bar{\epsilon} < D_H(p)\). As a result, only type \(H\)
consumers pay overage charges. The case where \( \bar{e} < D_L(p) < D_H(p) \) can be ruled out\(^4\), and whether the firms choose to raise \( \bar{e} \) above \( D_L(p) \) will be determined by the first order conditions.

The allocation of consumers between two firms is determined by utility maximization. A consumer will buy from the firm that provides the highest surplus. That is, a type-\( i \) consumer buys from firm \( j \) if

\[
u_i(t_i) - \max(0, t_i - \bar{e}_j) p_j - K_j > u_i(t_i) - \max(0, t_i - \bar{e}_i) p_i - K_i \quad \text{for } l \neq j	ag{3.22}\]

Thus, if both firms share both types of consumers, the utility from both firms should be equal for each type. With \( D_L(p) \leq \bar{e} < D_H(p) \), then firm 1’s maximization problem is

\[
\max_{\pi_1, t_1, p_1} \pi_1 = (n_{1L} + n_{1H}p_1(D_H(p_1) - \bar{e}_1) - \beta\{n_{1L}\bar{e}_1 + n_{1H}D_H(p_1)\}
\]

s.t. \( u_H(D_H(p_1)) - p_1(D_H(p_1) - \bar{e}_1) - K_1 = u_H(D_H(p_2)) - p_2(D_H(p_2) - \bar{e}_2) - K_2 \)

\[u_L(\bar{e}_1) - K_1 = u_L(\bar{e}_2) - K_2 \tag{3.24}\]

Letting \( \lambda \) and \( \delta \) denote the Lagrangian multiplier for the constraints (3.23) and (3.24), the first order conditions are given by

\[^4\text{Suppose that } \bar{e} \leq D_L(p) < D_H(p). \text{ Then a given firm’s profit is written as } (n_L + n_H)k + n_Hp(D_H(p) - \bar{e}) + n_Lp(D_L(p) - \bar{e}) - \beta\{n_LD_L(p) + n_HD_H(p)\}. \]

Two incentive compatibility constraints are as follows:

\[
\text{s.t. } u_H(D_H(p)) - p(D_H(p) - \bar{e}) - K = \bar{u}_H \quad \text{(f1)}
\]

\[
u_L(D_L(p)) - p(D_L(p) - \bar{e}) - K = \bar{u}_L, \quad \text{(f2)}
\]

given values for \( \bar{u}_H \) and \( \bar{u}_L \) which are consumer surplus determined by rival’s prices. (f1) and (f2) can be rewritten as \( K = u_H(D_H(p)) - p(D_H(p) - \bar{e}) - \bar{u}_H \) and \( K = u_L(D_L(p)) - p(D_L(p) - \bar{e}) - \bar{u}_L \), respectively. By plugging them into the profit expression, the following is obtained:

\[
\begin{align*}
&n_Hu_H(D_H(p)) - n_Hp(D_H(p) - \bar{e}) - n_H\bar{u}_H + n_Lu_L(D_L(p)) - n_Lp(D_L(p) - \bar{e}) - n_L\bar{u}_L + n_Hp(D_H(p) - \bar{e}) + n_Lp(D_L(p) - \bar{e}) - \beta\{n_LD_L(p) + n_HD_H(p)\} \\
&= n_Hu_H(D_H(p)) + n_Lu_L(D_L(p)) - \beta\{n_LD_L(p) + n_HD_H(p)\} - n_H\bar{u}_H - n_L\bar{u}_L
\end{align*}
\]

Since the additional usage above the allowance is eliminated, the profit is independent of \( \bar{e} \) when \( \bar{e} \leq D_L(p) < D_H(p) \). Therefore, \( \bar{e} \) can be set initially such that \( D_L(p) = \bar{e} < D_H(p) \), and it is justifiable that the analysis focuses only on the case of \( D_L(p) \leq \bar{e} < D_H(p) \).
\( K_1 : (n_{1L} + n_{1H}) - \lambda - \delta = 0, \)  
(3.25)

\( \bar{e}_1 : - n_{1H} p_1 - \beta n_{1L} + \lambda p_1 + \delta u_L'(\bar{e}_1) = 0, \)
(3.26)

\( p_1 : n_{1H} (D_H(p_1) - \bar{e}_1) + n_{1H} p_1 D_H'(p_1) - \beta n_{1H} D_H'(p_1) + \lambda (\beta n_{1H} D_H'(p_1) + \bar{e}_1) = 0, \)  
(3.27)

\( \lambda : u_H(D_H(p_1)) - p_1 (D_H(p_1) - \bar{e}_1) - K_1 - u_H(D_H(p_2)) + p_2 (D_H(p_2) - \bar{e}_2) + K_2 = 0, \)  
(3.28)

\( \delta : u_L(\bar{e}_1) - K_1 - u_L(\bar{e}_2) + K_2 = 0. \)  
(3.29)

Plugging (3.25) into (3.26) gives

\[- n_{1H} p_1 - \beta n_{1L} + \lambda p_1 + (n_{1L} + n_{1H} - \lambda) u_L'(\bar{e}_1) = 0, \]
(3.30)

which can be rewritten as

\[ (n_{1L} - \lambda) (u_L'(\bar{e}_1) - p_1) + n_{1L} (u_L'(\bar{e}_1) - \beta) = 0. \]
(3.31)

The conditions (3.27) can be rewritten as

\[ (n_{1H} - \lambda) (D_H(p_1) - \bar{e}_1) + n_{1H} D_H'(p_1) (p_1 - \beta) = 0 \]
(3.32)

In this setting, we need to consider the Bertrand competition logic, that is, firms’ undercutting incentives. The firm that sets lower prices than a rival’s by only a penny will capture all consumers, so that both firms would keep undercutting the rival’s prices until their profits become zero. However, with two types of consumers, pricing at zero total profit might not always be an equilibrium. For instance, the case where firms make a loss from one type and a profit from the other type cannot be achieved as equilibrium since both firms will end up not wanting to serve the consumers who cause losses. Therefore, with heterogeneous consumers, a firm’s undercutting incentive needs to be considered for each type separately, and the prices at
equilibrium turn out to result in a zero profit from each consumer type, with the two following conditions satisfied:

\[
n_{1H}K_1 + n_{1H}p_1(D_H(p_1) - \bar{e}_1) - \beta n_{1H} D_H(p_1) = 0 \quad (3.33)
\]
\[
n_{1L}K_1 - \beta n_{1L} \bar{e}_1 = 0. \quad (3.34)
\]
Condition (3.33) is firm 1’s zero profit condition for type \(H\) consumers, which implies that, at equilibrium prices, firm 1 will not have an incentive to take \(H\)-types from the rival firm by cutting the prices further. Similarly, the condition (3.34), a zero profit condition for type \(L\), implies that, at equilibrium prices, firm 1 will not have an incentive to take \(L\)-types from the rival firm by cutting prices further.

The equation (3.34) implies \(K_1 = \beta \bar{e}_1\), so that the lump sum fee just covers the cost of the allowance consumption level. Substituting for \(K_1\) in equation (3.33), the equation reduces to

\[
(p_1 - \beta)(D_H(p_1) - \bar{e}_1) = 0. \quad (3.35)
\]
If \(D_H(p_1) = \bar{e}_1\), then it must be true that \(p_1 = \beta\) from (3.31), implying \(u_L'(\bar{e}_1) = \beta\) from (3.32). This implies \(D_H(\beta) = D_L(\beta) = \bar{e}_1\), which is contradictory to the assumption \(u_H' > u_L'\). Therefore, \(D_H(p_1) > \bar{e}_1\) must hold, implying \(p_1 = \beta\) from (3.35).\(^{49}\) Substituting \(p_1 = \beta\), the equation (3.31) can be rewritten as

\[
(n_{1H} + n_{1L} - \lambda)(u_L'(\bar{e}_1) - \beta) = 0. \quad (3.36)
\]
Since the first term equals \(\delta > 0\), it follows that \(u_L'(\bar{e}_1) = \beta\) must hold. Given the symmetric pricing strategy of firm 2, both firms’ pricing meet the conditions in (3.34) – (3.36).

To summarize, in a symmetric three-part tariff pricing game where both types of consumers are served by each firm, the three-part tariff at equilibrium is characterized by

\(^{49}\) Equation (3.32) is satisfied when \(\lambda = n_{1H}\) and \(p_1 = \beta\).
\[ p = \beta, \quad u_H'(t^*_H) = u_L'(\bar{t}) = \beta, \quad K = \beta \bar{t}, \quad (3.37) \]

where \( t^*_H = D_H(\beta) \).

In equilibrium, type \( L \) consumes at the allowance level, and only type \( H \) pays overage charges. Both types’ marginal utilities equal marginal cost in duopoly, so that the outcome is efficient.

The following comparison to the monopoly case can be made. The per unit price in the duopoly case is lower than in the monopoly case, and the usage cap is greater than in monopoly case, where \( u_L'(\bar{t}) > \beta \) holds. Whether a lump sum fee is lower or not in duopoly than in monopoly is ambiguous as shown in Figure 3.2-1 and Figure 3.2-2 below. Figure 3.2-1 shows that monopoly firm charges a lump sum fee as much as the area of \( ABCO \) while a firm in duopoly charges the area of \( \beta DEO \) in Figure 3.2-2 for a lump sum fee. Therefore, which area is bigger is ambiguous, depending on the demand curve of low demand consumers. It is obvious that consumers’ optimal usage and surpluses increase for both types and firms end up with zero profits in duopoly.

**Figure 3.2-1. Monopoly**

**Figure 3.2-2. Duopoly**
Although our result shows that there is an equilibrium with symmetric three-part tariffs, other equilibria may exist when asymmetric strategies are considered. Therefore, other possible market segmentations with asymmetric strategies are explored in Appendix to see if they can arise as equilibria. It turns out that asymmetric equilibria don’t exist.

3.5. Conclusion

We have analyzed three-part tariffs in both monopoly and duopoly settings where firms’ products are homogeneous and consumers are classified into two groups. The aim of this analysis is to characterize the optimal three-part tariff plans in both monopoly and duopoly cases, and to explore whether the implementation of a three-part tariff in the presence of heterogeneous consumers leads to a standard Bertrand competition outcome.

When a monopoly firm faces two user groups, the optimal lump sum fee will be raised to the point where the consumer type with the smaller willingness to pay is fully exploited. This increases profits and insures that all consumers remain in the market. The optimal per unit price is above marginal cost. At the optimal allowance level, the low-demand type’s marginal utility is less than marginal price, and greater than marginal cost. This result implies that the monopoly firm raises the allowance level higher than the actual demand of low-demand consumers at optimal marginal price, so that it could maximize the profits from a lump sum fee. Nevertheless, the low-demand type’s consumption is still low from a social viewpoint.

The study then considers a homogeneous-product Bertrand duopoly and analyzes the firms’ equilibrium strategies. We find that asymmetric equilibria do not exist, and only a symmetric three-part tariff where both firms will share both types of consumers can be achieved as an equilibrium. In this case, the usage cap is set equal to the low demand consumer’s optimal
usage at the marginal price, so that the low demand consumer’s marginal utility at the allowance level equals to marginal cost. The marginal price equals marginal cost, so that the high demand consumer’s marginal utility is also equal to marginal cost, which is optimal from a social viewpoint. In comparison with the monopoly case, the marginal price in the duopoly case is lower, and the usage cap is greater. Whether lump sum fees in duopoly are lower or not is ambiguous since it depends on the demand curve of low demand consumers.

The results for the duopoly case show that the simple Bertrand competition logic, that is, price competition between identical firms in homogeneous goods markets leads to pricing at cost and zero profits, can apply to the case of three-part tariffs. Three-part tariffs with demand heterogeneity allow a firm more flexibility to take advantage of price discrimination, increasing the chance of positive profits. However, it is confirmed that a standard Bertrand outcome still holds in a simple duopoly setting. By contrast, in a monopoly setting, the three-part tariff can be used as a means of boosting profit, with the full extraction of the low demand type’s surplus through lump sum fee.
Appendix 3

A3.1. Case (B): Firm 1 serves only type L and firm 2 serves only type H

Proposition A1

There is no equilibrium where firm 1 serves only consumer type L and firm 2 serves only consumer type H.

To prove this proposition, observe that, since each firm faces identical consumers, it will be most profitable to charge only a lump sum fee by setting a usage cap as big as possible, exhausting the surplus of the consumer type served. Therefore, it can be assumed that consumers pay only lump sum fees $K_j$ in each firm and marginal prices $p_j$ are set arbitrarily high. Case (B) cannot be established as equilibrium since type $H$ consumers would have an incentive to join the same firm as type $L$ consumers, since $u_H(\bar{e}_1) > u_L(\bar{e}_1) = K_1$, which implies that type $H$ consumers would enjoy positive rather than zero surplus.50

A3.2. Case (C): Firm 1 serves both type L and type H, firm 2 serves type H

Proposition A2

There is no equilibrium where firm 1 serves both type L and type H and firm 2 serves type H.

Suppose firm 1 serves both type L and type H consumers while firm 2 serves only type $H$ consumers. Regarding firm 1’s optimal usage cap, two cases are possible: (i) $D_L(p_1) \leq \bar{e}_1 \leq$

---

50 Firm 1 could cut $K_1$ enough to make type $H$ indifferent between the firms. This case is also contradictory to the assumption of strict separation of the types in Case (B). This is the case where both firms charge only lump sum fees, type $H$ are split to two firms, and type $L$ stay in firm 1, which is the special case of Case (C). It will be proved later that Case (C) cannot be an equilibrium.
\( D_H(p_1) \), (ii) \( \bar{\epsilon}_1 \leq D_L(p_1) < D_H(p_1) \). As proved in footnote 6 in Section 4, when duopoly firms share both types of consumers, the case of \( \bar{\epsilon} < D_L(p) < D_H(p) \) can be ruled out. Similarly, in the market segmentation of Case (C), the firm serving both types will set \( \bar{\epsilon} \) at \( D_L(p) \leq \bar{\epsilon} \leq D_H(p) \) as proven in the following paragraphs.

Suppose that \( \bar{\epsilon} \leq D_L(p) < D_H(p) \). Then, the profit of a firm serving both type is

\[
(n_L + n_H)K + n_H p(D_H(p) - \bar{\epsilon}) + n_L p(D_L(p) - \bar{\epsilon}) - \beta \{n_L D_L(p) + n_H D_H(p)\}
\]

If this firm shares type \( H \) with rival firm, then two constraints are as follows:

\[
s.t. \ u_H(D_H(p)) - p(D_H(p) - \bar{\epsilon}) - K = \bar{u}_H \quad (A3.1)
\]

\[
u_L\left(D_L(p)\right) - p\left(D_L(p) - \bar{\epsilon}\right) - K \geq 0 , \quad (A3.2)
\]

given value for \( \bar{u}_H \) which is consumer surplus determined by rival’s prices. (A3.1) can be rewritten as \( K = u_H(D_H(p)) - p(D_H(p) - \bar{\epsilon}) - \bar{u}_H \). By plugging it into the profit expression, the following is obtained:

\[
= n_L \left(u_H\left(D_H\left(p\right)\right) - p\left(D_H\left(p\right) - \bar{\epsilon}\right) - \bar{u}_H\right) + n_H \left(u_H\left(D_H\left(p\right)\right) - p\left(D_H\left(p\right) - \bar{\epsilon}\right) - \bar{u}_H\right) +
\]

\[
n_H p\left(D_H\left(p\right) - \bar{\epsilon}\right) + n_L p\left(D_L\left(p\right) - \bar{\epsilon}\right) - \beta \{n_L D_L(p) + n_H D_H(p)\}
\]

\[
= (n_H + n_L)u_H\left(D_H\left(p\right)\right) - n_L p\left(D_H\left(p\right) - D_L\left(p\right)\right) - \beta \{n_L D_L(p) + n_H D_H(p)\} - (n_H + n_L)\bar{u}_H
\]

Eliminating \( K \) using the constraint (A3.1), the additional usage above the allowance is eliminated from the firm’s profit expression. Also, the first order conditions with constraint (A3.2) show that the changes in \( \bar{\epsilon} \) don’t affect the profit, although the conditions are not reported here. Thus, the profit of this firm is independent of \( \bar{\epsilon} \) when \( \bar{\epsilon} \leq D_L(p) < D_H(p) \). Therefore, \( \bar{\epsilon} \) can be set initially such that \( D_L(p) = \bar{\epsilon} \), and the case of \( \bar{\epsilon} < D_L(p) < D_H(p) \) can be ruled out.

---

\( ^{51} \) Since \( D_L(p_1) < D_H(p_1) \), the inequality cannot hold as two equalities.
Assuming that firm 1 will set $\bar{t}_1$ at $D_L(p_1) \leq \bar{t}_1 \leq D_H(p_1)$, we still have two cases of $\bar{t}_2$:

(i) $\bar{t}_2 \leq D_H(p_2)$, (ii) $\bar{t}_2 \geq D_H(p_2)$, and each case will be examined in the following paragraphs.

**Case (i) $\bar{t}_2 \geq D_H(p_2)$**

In this case, firm 2 charges only a lump sum fee to type $H$ consumers. Thus, firm 2’s profit maximization problem is,

$$\max_{\{K_2, \bar{t}_2\}} n_2 H(K_2 - \beta \bar{t}_2)$$

s.t. $u_H(\bar{t}_2) - K_2 = u_H(D_H(p_1)) - p_1(D_H(p_1) - \bar{t}_1) - K_1$

Letting $\lambda$ denote the Lagrangian multiplier for the constraint, the first order conditions are given by

$$K_2: \ n_{2H} - \lambda = 0 \quad (A3.3)$$

$$\bar{t}_2: - \beta n_{2H} + \lambda u_H'(\bar{t}_2) = 0 \quad (A3.4)$$

The solution of firm 2’s profit maximization problem yields

$$u_H'(\bar{t}_2) = \beta, \text{ i.e., } D_H(\beta) = \bar{t}_2. \quad (A3.5)$$

Now, firm 1’s profit maximization problem is,

$$\max_{K_1, p_1, \bar{t}_1} (n_L + n_{1H}K_1 + n_{1H}p_1(D_H(p_1) - \bar{t}_1) - \beta (n_L \bar{t}_1 + n_{1H}D_H(p_1)))$$

s.t. $u_H(D_H(p_1)) - p_1(D_H(p_1) - \bar{t}_1) - K_1 = u_H(\bar{t}_2) - K_2$, \quad (A3.6)

$$u_L(\bar{t}_1) - K_1 \geq 0. \quad (A3.7)$$

Since type $L$ consumers are served only by firm 1, the firm faces a participation constraint and not an equal-surplus constraint for such consumers. But, since both firms share type $H$, the
surplus from both firms should be equal as shown in the (A3.6). Additionally, for Case (C) to be achieved as market segmentation at equilibrium, the following condition should hold:

\[ u_L(\bar{e}_1) - K_1 > u_L(\bar{e}_2) - K_2 \]  

(A3.8)

Letting \( \lambda \) and \( \mu \) denote the Lagrangian multipliers for the constraint (A3.6) and (A3.7), the first order conditions are given by

\begin{align*}
K_1: & \quad (n_L + n_{1H}) - \lambda - \mu = 0 \quad \text{(A3.9)} \\
p_1: & \quad n_{1H} \left( D_H(p_1) - \bar{e}_1 + p_1D_H'(p_1) - \beta D_H'(p_1) \right) - \lambda(D_H(p_1) - \bar{e}_1) = 0 \quad \text{(A3.10)} \\
\bar{e}_1: & \quad -n_{1H}p_1 - \beta n_L + \lambda p_1 + \mu u_L'(\bar{e}_1) = 0 \quad \text{(A3.11)} \\
\lambda: & \quad u_H(D_H(p_1)) - p_1(D_H(p_1) - \bar{e}_1) - K_1 - u_H(\bar{e}_2) + K_2 = 0 \quad \text{(A3.12)} \\
\mu(u_L(\bar{e}_1) - K_1) = 0, \quad \mu \geq 0, \quad u_L(\bar{e}_1) \geq K_1 \quad \text{(A3.13)}
\end{align*}

As discussed in Section 3.4, in Bertrand price competition, a firm will undercut a rival’s price to capture more consumers. In this case, two firms compete with each other for more type \( H \) consumers by undercutting the rival’s prices until profit from type \( H \) approaches zero. Therefore, the following condition must hold:

\[ n_{1H} \{ K_1 + p_1(D_H(p_1) - \bar{e}_1) - \beta D_H(p_1) \} = 0 . \quad \text{(A3.14)} \]

Similarly, a firm 2 won’t steal type \( H \) consumers from firm 1 by cutting prices further if

\[ n_{2H}(K_2 - \beta \bar{e}_2) = 0 . \quad \text{(A3.15)} \]

Based on the zero profit condition (A3.15), we obtain

\[ K_2 = \beta \bar{e}_2 . \quad \text{(A3.16)} \]
Therefore, from (A3.5) and (A3.16), the optimal prices of firm 2 are

$$\bar{e}_2 = D_H(\beta), \quad K_2 = \beta \bar{e}_2.$$  \hfill (A3.17)

After plugging (A.9) into (A.11), rearranging (A.11) yields

$$(n_L - \mu)p_1 = \beta n_L - \mu u_L'(\bar{e}_1).$$  \hfill (A3.18)

Thus, it follows that

$$\mu(u_L'(\bar{e}_1) - p_1) = n_L(\beta - p_1)$$  \hfill (A3.19)

Rewriting (A3.10) gives

$$n_{1H}D_H'(p_1)(p_1 - \beta) = -n_{1H}(D_H(p_1) - \bar{e}_1) + (n_L + n_{1H} - \mu)(D_H(p_1) - \bar{e}_1)$$

$$= (n_L - \mu)(D_H(p_1) - \bar{e}_1)$$  \hfill (A3.20)

If the participation constraint (A.13) doesn’t bind, i.e., $\mu = 0$, then we have

$$p_1 = \beta, \quad K_1 = \beta \bar{e}_1.$$  \hfill (A3.21)

from (A3.19) and (A3.14). If $p_1 = \beta$, $D_H(\beta)$ should be equal to $\bar{e}_1$ from the second line of (A3.20), which implies $\bar{e}_1 = \bar{e}_2$ from (A3.17) and $K_1 = \beta \bar{e}_1 = \beta \bar{e}_2 = K_2$. With these prices, it should hold that $u_L(\bar{e}_1) - K_1 = u_L(\bar{e}_2) - K_2$, which contradicts condition (A3.8).

Now, consider the case when the participation constraint (A3.13) binds, i.e., $\mu > 0$ and $u_L(\bar{e}_1) = K_1$. Since $\mu > 0$, $u_L'(\bar{e}_1)$ is greater than $p_1$ if $p_1 < \beta$, which is a contradiction to the assumption of $D_L(p_1) \leq \bar{e}_1$. Therefore, if $\mu > 0$, then it must be that $p_1 > \beta$ and $u_L'(\bar{e}_1) < p_1$.

Let’s check if $p_1 > \beta$ can be equilibrium feature when $\mu > 0$. The zero profit condition (A3.14) can be rewritten as
\[ K_1 = p_1 (\bar{E}_1 - D_H(p_1)) + \beta D_H(p_1), \quad (A3.22) \]

and constraint (A3.12) gives

\[ K_1 = u_H(D_H(p_1)) - p_1 (D_H(p_1) - \bar{E}_1) - u_H(\bar{E}_2) + K_2 = p_1 (\bar{E}_1 - D_H(p_1)) + \beta D_H(p_1). \quad (A3.23) \]

Combining (A3.22) and (A3.23) gives,

\[ u_H(D_H(p_1)) - p_1 (D_H(p_1) - \bar{E}_1) - u_H(\bar{E}_2) + K_2 = p_1 (\bar{E}_1 - D_H(p_1)) + \beta D_H(p_1). \quad (A3.24) \]

Rearranging (A3.24) yields,

\[ u_H(\bar{E}_2) - u_H(D_H(p_1)) = \beta (\bar{E}_2 - D_H(p_1)), \quad (A3.25) \]

and (A3.25) cannot be true for any \( p_1 > \beta \) when \( \bar{E}_2 = D_H(\beta) \) as shown in Figure A3.1.\(^{52}\) In the Figure A3.1, the left hand side of (A3.25) is the area \( ADEC \), and the right hand side is the area \( BDEC \), so that the left hand side is always greater when \( p_1 > \beta \). Therefore, we found that the optimal \( p_1 \) cannot be greater than \( \beta \) when the participation constraint (A3.7) binds, i.e., \( \mu > 0 \) and \( u_L(\bar{E}_1) = K_1 \). Therefore, when \( \bar{E}_2 \geq D_H(p_2) \), there is no equilibrium.

\[ D_H(p) = u_H'(t) \]

**Figure A3.1**

\(^{52}\) \( D_H(\beta) = \bar{E}_2 \) was derived from firm 2’s optimization problem in (A3.5).
Case (ii) \( \bar{\epsilon}_2 \leq D_H(p_2) \)

In this case, firm 2 charges type \( H \) consumers both a lump sum fee and overage charge. Thus, firm 2’s profit maximization problem is,

\[
\max_{\{k_2, \bar{\epsilon}_2, p_2\}} \ n_{2H} K_2 + n_{2H} p_2 (D_H(p_2) - \bar{\epsilon}_2) - n_{2H} \beta D_H(p_2)
\]

s.t. \( u_H(D_H(p_2)) - p_2 (D_H(p_2) - \bar{\epsilon}_2) - K_2 = u_H(D_H(p_1)) - p_1 (D_H(p_1) - \bar{\epsilon}_1) - K_1. \) \hspace{1cm} (A3.26)

The constraint (A.26) can be rewritten as

\[
K_2 = u_H(D_H(p_2)) - p_2 (D_H(p_2) - \bar{\epsilon}_2) - u_H(D_H(p_1)) + p_1 (D_H(p_1) - \bar{\epsilon}_1) + K_1. \hspace{1cm} (A3.27)
\]

By plugging (A3.27) into the objective function in firm 2’s profit maximization problem gives

\[
n_{2H} K_2 + n_{2H} p_2 (D_H(p_2) - \bar{\epsilon}_2) - n_{2H} \beta D_H(p_2)
\]

\[
= n_{2H} \{ u_H(D_H(p_2)) - p_2 (D_H(p_2) - \bar{\epsilon}_2) - u_H(D_H(p_1)) + p_1 (D_H(p_1) - \bar{\epsilon}_1) \} + K_1 + p_2 (D_H(p_2) - \bar{\epsilon}_2) - \beta D_H(p_2) \}
\]

\[
= n_{2H} \{ u_H(D_H(p_2)) - u_H(D_H(p_1)) + K_1 - \beta D_H(p_2) \}.
\]

Since the additional usage above the allowance, \( D_H(p_2) - \bar{\epsilon}_2 \), is eliminated from firm 2’s profit expression, the profit is independent of \( \bar{\epsilon}_2 \). Therefore, \( \bar{\epsilon}_2 \) can be set initially so that \( \bar{\epsilon}_2 = D_H(p_2) \) yielding the problem already solved in Case (i), which implies there is no equilibrium in Case (ii) as well.

This result has an interesting aspect as it shows that there does not exist a “Cream Skimming” firm which serves only more profitable consumers in equilibrium. As proved in this section, both firms should eventually set prices at cost, where type \( L \) consumers will also be indifferent between the two firms. Therefore, an asymmetric equilibrium under Case (C) does not exist.
A3.3. Case (D): Firm 1 serves only type L and firm 2 serves both type L and type H

**Proposition A3**

*There is no equilibrium where firm 1 serves only type L and firm 2 serves both type L and type H.*

If firm 2 offers a higher lump sum fee and allowance and a lower marginal price than firm 1 does, and prices make the surpluses of type L consumers from both firms equal, then the market segmentation of Case (D) might appear to be an asymmetric equilibrium. However, it turns out that Case (D) cannot be achieved as an equilibrium, and the proof is as follows.

As discussed in Section A3.2, it can be assumed that firm 2, serving both types of consumers will set \( \bar{t}_2 \) at \( D_L(p_2) \leq \bar{t}_2 \leq D_H(p_2) \). Now, regarding firm 1’s optimal usage cap, two cases need to be considered: (i) \( \bar{t}_1 \leq D_L(p_1) \), (ii) \( \bar{t}_1 \geq D_L(p_1) \), and each case will be examined in the following paragraphs.

**Case (i) \( \bar{t}_1 \geq D_L(p_1) \)**

This case is when marginal prices are sufficiently high, so that type L doesn’t pay overage charges to either firm 1 or firm 2. If both firms share type L, the utility from both firms should be equal as shown in the relevant participation constraints.

Firm 1’s maximization problem is

\[
\max_{\kappa, \ell, n_{1L}} n_{1L}K_1 - \beta n_{1L} \bar{t}_1 \\
\text{s.t. } u_L(\bar{t}_1) - K_1 = u_L(\bar{t}_2) - K_2
\]  

(A3.28)

Letting \( \lambda \) denote the Lagrangian multiplier for the constraint (A3.28), the first order conditions are given by
\[ K_1: \ n_{1L} - \lambda = 0, \quad (A3.29) \]
\[ \bar{\epsilon}_1: \ -\beta n_{1L} + \lambda u'_L(\bar{\epsilon}_1) = 0, \quad (A3.30) \]
\[ \lambda: \ u_L(\bar{\epsilon}_1) - K_1 = u_L(\bar{\epsilon}_2) - K_2. \quad (A3.31) \]

Solving firm 1’s maximization problem gives

\[ u'_L(\bar{\epsilon}_1) = \beta \quad \text{or} \quad \bar{\epsilon}_1 = D_L(\beta) \quad (A3.32) \]

Firm 2’s optimization problem is then as follows\(^{53}\):

\[
\max_{k_2, \bar{\epsilon}_2, p_2} (n_{2L} + n_H)K_2 + n_H p_2(D_H(p_2) - \bar{\epsilon}_2) - \beta(n_{2L} \bar{\epsilon}_2 + n_H D_H(p_2))
\]
\[
\text{s.t.} \quad u_H(D_H(p_2)) - p_2(D_H(p_2) - \bar{\epsilon}_2) - K_2 \geq 0 \quad (A3.33)
\]
\[ u_L(\bar{\epsilon}_2) - K_2 = u_L(\bar{\epsilon}_1) - K_1 \quad (A3.34) \]

The constraint (A3.33) in firm 2’s problem is the participation constraint for type \(H\). Letting \(\lambda\) and \(\mu\) denote the Lagrangian multipliers for the constraint (A3.33) and (A3.34), the first order conditions are given by

\[ K_2: \ (n_{2L} + n_H) - \lambda - \mu = 0 \quad (A3.35) \]
\[ \bar{\epsilon}_2: \ -n_H p_2 - n_{2L} \beta + \lambda p_2 + \mu u'_L(\bar{\epsilon}_2) = 0 \quad (A3.36) \]
\[ p_2: \ n_H(D_H(p_2) - \bar{\epsilon}_2) + p_2 n_H D_H'(p_2) - \beta n_H D_H'(p_2) + \lambda(\bar{\epsilon}_2 - D_H(p_2)) = 0 \quad (A3.37) \]
\[ \lambda(u_H(D_H(p_2)) - p_2(D_H(p_2) - \bar{\epsilon}_2) - K_2) = 0, \quad \text{and} \]
\[ \lambda \geq 0, \quad u_H(D_H(p_2)) - p_2(D_H(p_2) - \bar{\epsilon}_2) - K_2 \geq 0 \quad (A3.38) \]

\(^{53}\) Since type \(H\) consumers are served only by firm 2, the firm faces a participation constraint and not an equal-surplus constraint for such consumers. But, since both firms share type \(L\), the surplus from both firms should be equal as shown in the (A3.34). Additionally, for Case (D) to be achieved as market segmentation at equilibrium, the following condition should hold:

\[ u_H(D_H(p_2)) - p_2(D_H(p_2) - \bar{\epsilon}_2) - K_2 > u_H(D_H(p_1)) - p_1(D_H(p_1) - \bar{\epsilon}_1) - K_1 \]
\[ \mu: u_L(\bar{e}_2) - K_2 - u_L(\bar{e}_1) + K_1 = 0 \]  
(A3.39)

Both firms compete with each other for type \( L \) by undercutting rival’s prices until its profit from type \( L \) approaches zero. The following condition (A3.40) and (A3.41) implies that a firm 1 and firm 2 will earn zero profit from type \( L \) at equilibrium.

\[ n_{1L}(K_1 - \beta \bar{e}_1) = 0 \]  
(A3.40)

\[ n_{2L}(K_2 - \beta \bar{e}_2) = 0 \]  
(A3.41)

using the condition that each firm will have zero profit from type \( L \) at equilibrium yields

\[ K_1 = \beta \bar{e}_1, \quad K_2 = \beta \bar{e}_2. \]  
(A3.42)

Plugging (A3.42) into (A3.39) gives

\[ u_L(\bar{e}_2) - \beta \bar{e}_2 = u_L(\bar{e}_1) - \beta \bar{e}_1. \]  
(A3.43)

and (A3.43) holds only when \( \bar{e}_1 = \bar{e}_2 \).

Let’s check if \( \bar{e}_1 = \bar{e}_2 \) can hold in equilibrium. Suppose that the participation constraint (A3.38) is not binding, that is, \( \lambda = 0 \). Then, from (A3.35) and (A3.36), we have \( p_2 = \beta \).

Plugging \( p_2 = \beta \) into (A3.37) gives \( \bar{e}_2 = D_H(\beta) \). Since \( \bar{e}_1 = D_L(\beta) \) from (A3.32), \( \bar{e}_1 \) then cannot be equal to \( \bar{e}_2 \), which is contradictory to the outcome of (A3.43). Therefore, it must be that \( \lambda > 0 \), which implies that the constraint (A3.38) is binding. Plugging \( \bar{e}_1 = \bar{e}_2 \) into (A3.36) gives the following:

\[ -n_H p_2 - n_{2L} \beta + \lambda p_2 + \mu u_L'(\bar{e}_1) = -n_H p_2 - n_{2L} \beta + \lambda p_2 + \mu \beta \]

\[ = -n_H p_2 - n_{2L} \beta + \lambda p_2 + (n_{2L} + n_H - \lambda) \beta \]

\[ = (n_H - \lambda) (p_2 - \beta) = 0. \]  
(A3.44)
The condition (A3.37) can be rewritten as

$$ (n_H - \lambda)(D_H(p_2) - \bar{\epsilon}_2) + (p_2 - \beta)n_H D_H'(p_2) = 0. $$  \hspace{1cm} (A3.45)

Therefore, combining (A3.44) and (A3.45) yields

$$ p_2 = \beta, \quad n_H = \lambda, $$  \hspace{1cm} (A3.46)

which contradicts (A3.38) since it cannot be binding if $p_2 = \beta$, $K_2 = \beta \bar{\epsilon}_2$. Therefore, there is no equilibrium where $\bar{\epsilon}_1 \geq D_L(p_1)$ in Case (D).

**Case (ii) $\bar{\epsilon}_1 \leq D_L(p_1)$**

This case is when marginal price $p_1$ is relatively low, so that type $L$ consumers who choose firm 1 pay overage charges for usage above the usage cap. If both firms share type $L$, the surplus from both firms should be equal as shown in the relevant participation constraints.

Firm 1’s optimization problem is

$$ \max_{K_1, \bar{\epsilon}_1} n_{1L} K_1 + n_{1L} p_1 (D_L(p_1) - \bar{\epsilon}_1) - n_{1L} \beta D_L(p_1) $$

s.t. $u_L(D_L(p_1)) - p_1 (D_L(p_1) - \bar{\epsilon}_1) - K_1 = u_L(\bar{\epsilon}_2) - K_2. $  \hspace{1cm} (A3.47)

The constraint (A3.47) can be rewritten as

$$ K_1 = u_L(D_L(p_1)) - p_1 (D_L(p_1) - \bar{\epsilon}_1) - u_L(\bar{\epsilon}_2) + K_2. $$  \hspace{1cm} (A3.48)

By plugging (A3.48) into the objective function in firm 1’s profit maximization problem gives

$$ n_{1L} K_1 + n_{1L} p_1 (D_L(p_1) - \bar{\epsilon}_1) - n_{1L} \beta D_L(p_1) $$

$$ = n_{1L} \{ u_L(D_L(p_1)) - p_1 (D_L(p_1) - \bar{\epsilon}_1) - u_L(\bar{\epsilon}_2) + K_2 \} + n_{1L} p_1 (D_L(p_1) - \bar{\epsilon}_1) - n_{1L} \beta D_L(p_1) $$

$$ = n_{1L} \{ u_L(D_L(p_1)) - u_L(\bar{\epsilon}_2) + K_2 - \beta D_L(p_1) \}.$$
Since the additional usage above the allowance, $D_L(p_1) - \bar{t}_1$, is eliminated from firm 1’s profit expression, the profit is independent of $\bar{t}_1$. Therefore, $\bar{t}_1$ can be set initially so that $\bar{t}_1 = D_L(p_1)$ yielding the problem already solved in Case (i), which implies there is no equilibrium in Case (ii) as well.
References


