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Multiproduct Firms, Product Bundling and Market Entry

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Abstract

High-speed Internet providers in the U.S. offer mixed bundling, which consists of subscription television, telephone, and high-speed Internet. This study aims to examine the two opposing influences of mixed bundling offered by an incumbent cable system on the probability of a telephone company's entry into the high-speed Internet market: the demand effects and the retention of consumers. In terms of demand effects, an incumbent's provision of mixed bundling implies market demand for mixed bundling and thus increases the probability of entry by the telephone company that prepares to provide mixed bundling. On the contrary, an incumbent's mixed bundling leads to the retention of consumers. As consumers are locked into mixed bundling offered by an incumbent cable system, this paper assumes that consumers are less likely to switch from an incumbent cable system's mixed bundling to high-speed Internet service offered by the entrant. In terms of the retention of consumers, it is expected that the probability of entry is decreased by an incumbent cable system's mixed bundling. Therefore, the probability of entry is determined by the relative size between demand effects and the retention of consumers created by an incumbent cable system's mixed bundling. To distinguish the retention of consumers from demand effects, this paper uses the interplay between mixed bundling provided by an incumbent cable system and measures of consumer preferences such as income and education. Empirical findings in this paper suggest that the probability of entry in the high-speed Internet market decreases with median income or average years of schooling in markets where an incumbent cable system offers mixed bundling. Since markets with higher income or more years of schooling can have higher opportunity costs of time taken to switch service providers, these findings imply that the probability of entry decreases with higher opportunity costs of time when an incumbent cable system offers mixed bundling.

Key words: Entry, High-speed Internet, Multiproduct firms

JEL Classification: L11, L15, L86, L96

1. INTRODUCTION

A widespread phenomenon in U.S. telecommunications markets is mixed bundling[1] where a single firm offers telephone and high-speed Internet in a bundle or separately in addition to subscription television ("TV"). Mixed bundling, which is also known as double-play, triple-play, or media convergence, reduces time and effort in procuring different goods and appeals to consumers. An existing firm's provision of mixed bundling has two opposing influences on the probability of entry: the demand effect and retention of consumers. An existing firm's mixed bundling implies the presence of market demand for mixed bundling service which can increase the probability of new entry by a potential multiproduct supplier. On the contrary, an existing firm's mixed bundling can imply consumer lock-in by an existing firm which leads consumers to be less likely to switch service providers. The retention of consumers can, in turn, decrease the probability of entry. By separating out these two opposing effects of an existing firm's mixed bundling, this paper aims to empirically examine the influence of mixed bundling offered by an existing firm on the probability of new entry in the U.S. residential high-speed Internet market. The entrant in this paper is Qwest Communications International, Inc. (the telephone company, hereafter), which begins to provide a digital subscriber line (DSL). A cable system[2] is an existing firm (an incumbent, hereafter), as it has offered mixed bundling before the DSL entry by the telephone company.

Prior studies on product bundling suggest that an existing firm's bundling helps with retention of consumers and forecloses the entry of a single-product provider (Whinston, 1990; Carlton and Waldman, 2002; Nalebuff, 2004; Peitz, 2008). Switching service providers entails costs involved in overcoming uncertainty about the quality of unfamiliar brands, learning costs associated with adapting to a new brand,

[1] Adams and Yellen (1976) discuss two different bundling strategies: *pure bundling*, in which the seller only offers the products in fixed proportions; and *mixed bundling*, in which buyers may either buy the products separately or purchase a bundle with fixed proportions of each. Consumers usually purchase subscription TV only, double-play (i.e., a bundle of subscription TV and telephone service or a bundle of subscription TV and high-speed Internet service), or triple-play (i.e., a bundle of subscription TV, telephone, and high-speed Internet service). Therefore, this paper focuses on mixed bundling.

[2] A cable system refers to a cable company in a given geographical market. Cable systems provide same services at the same price to all consumers. They typically serve cities and are regulated by the boundary of cities or the state.

difficulties stemming from the need for compatibility with existing equipment, and hassle costs involved in switching (Lehr, 1998; Thanassoulis, 2007; Hannan, 2011). With an increase in switching costs, consumers are reluctant to change service providers and intensify post-entry competition. However, product bundling offered by an existing firm can indicate a preference for purchasing different services in a single bill to avoid higher costs and time required to purchase them separately. This may increase the probability of entry by a multi-product supplier.

While this paper examines two opposing influences of mixed bundling on firm entry, it also adds to the previous literature on product bundling in telecommunications. Prince and Greenstein (2011) explore the relationship between product bundling and consumers' switching behavior in the U.S. telecommunications market. They suggest that households that have already purchased a bundle of TV, telephone, and high-speed Internet (i.e., triple-play) are less likely to switch service providers. While their study examines the influence of product bundling on consumers' choice of switching service providers in the telecommunications market, this paper focuses on the supply side and empirically examines the impact that product bundling (i.e., mixed bundling) has on a multi-product supplier's entry decision in the high-speed Internet market.

Thanassoulis (2011) builds a theoretical model of the convergence process, which consists of partial convergence (i.e., product bundling offered by a single firm) and full convergence (i.e., product bundling offered by multiple firms). Full convergence in this paper can be observed when an incumbent cable system offers cable modem service in addition to TV and the telephone company provides DSL service in addition to its telephone service. Thanassoulis (2011) suggests that intense competition in full convergence leads to more discounts in product bundling and, in turn, full convergence is not the natural end point of the convergence process. A similar pattern is observed in this paper. The telephone company does not always enter the high-speed Internet market in which an incumbent cable system offers mixed bundling. This observation suggests that full convergence is also not an equilibrium outcome under this study.

This study performs an empirical analysis to examine the influence of mixed bundling on the probability of Qwest's DSL entry decisions into markets served by an incumbent cable system during the years 2002, 2004, and 2006. Preliminary findings can provide empirical evidence of demand effects and the retention of consumers. Demand effects are found in a positive relationship between the probability of DSL entry and the mixed bundling offered by an incumbent. The entrant is more likely to enter the high-speed Internet market where an incumbent offers mixed bundling of TV, telephone, and high-speed Internet service. The retention of consumers is reflected in a negative relationship between the probability of DSL entry and average income (or average years of schooling) in a market in which an incumbent offers mixed bundling. While wages are likely to increase with income and education, time spent on switching preempts other activities. Opportunity costs of time incurred by switching service providers may increase with income and years of schooling and reduce the probability of DSL entry.

The remainder of this paper proceeds as follows. Section 2 provides background information on the U.S. high-speed Internet industry. Section 3 presents the descriptive model and Section 4 describes the data. Section 5 presents estimation results and Section 6 concludes the paper.

2. BACKGROUND ON THE HIGH-SPEED INTERNET INDUSTRY AND ENTRY

This paper examines the residential high-speed Internet[3] market. The two services of interest are cable modem and DSL. Cable operators either provide downstream Internet access over their own network and upstream access via a telephone line (i.e., one-way capability) or both upstream and downstream over the entire cable network (i.e., two-way capability), by using a hybrid coaxial-fiber architecture. As subscribers must install a dial-up telephone in order to upload data to the network, one way is not really high-speed. Local telephone companies provide DSL service using copper telephone wires and a DSL access multiplexer (Chen and Savage, 2011).

[3] According to the Federal Communications Commission (FCC), high-speed lines connect home to the Internet at speeds that exceed 200 kbps at least in one direction.

Both cable operators and telephone companies in the U.S. telecommunications industry have expanded their services since the 1990s. Table 1 demonstrates that cable modem and DSL are the dominant services in high-speed Internet markets with over 90 percent combined market share between 1999 and 2006. Cable modem service offered by cable operators accounted for 78 percent of national shares in high-speed Internet lines in 1999. Despite its decrease to 53 percent in 2006, market shares for cable modem service have been larger than that of DSL since 1999. Hausman et al. (2001) also highlight the historical dominance of cable modem service in the high-speed Internet market based on the market shares for cable operators during the initial diffusion of high-speed Internet service; for example, 83.6 percent in 1999 and 73.2 percent in 2000. Based on this information, this paper treats cable modem service as the first mover and DSL as the second mover in the U.S. high-speed Internet market.

Both cable operators and telephone companies provide mixed bundling of TV, telephone, and high-speed Internet. In addition to TV and cable modem service, cable operators have provided digital telephone service in the 2000s. Telephone companies have entered the high-speed Internet market since 1999 and have added television service. With its DSL entry, the entrant can become a multiproduct supplier. Qwest also formed a strategic marketing agreement with DirecTV in 2004 and began to provide TV services in most of their service areas in 2006. AT&T and Dish Network formed a partnership to begin TV service in 2003. Verizon formed a partnership with DirecTV in 2006 (Chan-Olmsted and Guo, 2011).

Qwest is one of the incumbent local exchange carriers (ILECs). The decision to study Qwest's DSL entry is deliberate. Among ILECs, the Federal Communications Commission (FCC) data on selected telephone companies demonstrate that Qwest has the largest facilities and revenues among potential DSL providers in the geographic areas[4] considered in this paper. After the passage of the 1996 Telecommunication Act, a number of new telephone companies, which are often called competitive local

[4] Among few primary providers of DSL service in Hausman et al. (2001), FCC data demonstrates that Qwest has contained the largest number of telephone lines in the geographic areas in this study since 1999 (see http://transition.fcc.gov/wcb/iatd/comp.html for information on telephone lines of selected telephone companies). Section 4.1 describes more detailed information about the geographic areas.

exchange carriers (CLECs) also began operations to provide DSL service. The CLECs tend to be smaller firms and use the ILECs' network infrastructure to provide DSL service. However, the CLECs' aggregate market shares were generally less than ten percent in any local telephone market in 2000 and a large number of the CLECs faced bankruptcy due to financial distress during the period from 2000 to 2002.[5] Failures of the CLECs lead Qwest to be the most likely facilities-based provider of DSL service in the geographic regions under consideration in this study among potential DSL providers. Qwest considered adding DSL service into its existing telephone service in markets in which at least one incumbent cable system existed and provided mixed bundling of TV, telephone, and high-speed Internet throughout most of their service areas in 2006.

Along with the growth of high-speed Internet access and mixed bundling in telecommunications since the late 1990s, there are specific features that lead us to focus on firm entry behaviors. First, the entrant and an incumbent cable system provide reasonably close substitutes in the high-speed Internet market. The high cross-price elasticity can be evidence of substitution between cable modem and DSL services. The demand for cable modem service rises by 0.59 percent for every one percent increase in the price of DSL service in Crandall et al. (2002), and the comparable elasticity from Rapporport et al. (2002) is 0.77 percent. High substitution between cable modem service and DSL opens up the possibility of switching from an incumbent cable system's mixed bundling to the telephone company's DSL service. Second, the telephone company provides reasonable continuity in the quality of service across markets due to its centralized business operations. This feature, after controlling for demand and cost conditions, allows for estimating the influence of an incumbent firm's characteristics (i.e., mixed bundling) and their interactions with market characteristics (i.e., preference of consumers) on the probability of entry. Third, the telephone company has provided telephone service by using its own local telephone network before

[5] According to Crandall and Sidak (2002), one of the major problems that had plagued CLECs was over-expansion that led to poor service quality, and, eventually, lost market share. For example, the average revenue growth of ICG Communications, Inc. (ICG) was approximately 9.1% per quarter, while the average growth of access lines was approximately 19% per quarter from 1998 to 2000. ICG was extracting less money for each access line over this time period and filed for bankruptcy in November 2000.

its DSL entry. Due to the presence of its own telephone network, the telephone company does not require huge sunk costs for its entry into the high-speed Internet market, and consumers have been aware of the telephone company before its DSL entry. Therefore, the retention of consumers led by an incumbent's product bundling can be a key determinant for the telephone company's DSL entry. Estimating the likelihood of switching from an incumbent's mixed bundling to DSL service offered by the telephone company can be a critical element to understand the telephone company's DSL entry decision. Lastly, high sunk costs in cable TV means that the exit or entry of cable systems is a very rare occurrence.[6] Unlike industries that experience significant firm turnover like manufacturing, for example, this paper focuses on the determinant of firm entry.

3. MODEL

The empirical model in this section explains the influence of mixed bundling offered by an incumbent cable system on the probability of the telephone company's DSL entry. The static entry model with complete information assumes the existence of both the entrant and an incumbent in market *i* at time *t*. DSL entry decisions of the entrant occur in two stages. While the entrant's profit (π_{it}^{*}) in a market cannot be directly observed, positive profits of the entrant will lead to DSL entry at stage one which is followed by competition with an incumbent who provides mixed bundling at stage two. Therefore, DSL entry in a market *i* at time *t* (*DSL Entry*$_{it}$)

$$DSL\ Entry_{it} = \begin{cases} 0, & if\ \pi_{it}^{*} < 0 \quad (no\ entry) \\ 1, & if\ \pi_{it}^{*} \geq 0 \quad (entry). \end{cases} \tag{1}$$

Following Bresnahan and Reiss (1991), the entrant's profit function is

$$\Pi = S \times V(\boldsymbol{Z}, \alpha, \beta) - F(\boldsymbol{W}, \gamma) + \varepsilon. \tag{2}$$

[6] In Warren Publishing (1999-2006), which provides data on cable systems, the entry or exit of cable systems is rarely observed.

Market size (S) is proxied by total population in a market. $V(\cdot)$ is variable profits and $F(\cdot)$ is fixed costs. $\boldsymbol{Z}$ and $\boldsymbol{W}$ are vectors of market-specific variables affecting variable profits and costs, respectively. α, β, and γ are profit function parameters to be estimated and ε is an unobserved random error term.

Variable profits could vary across markets and depend on competition intensity. This paper estimates the influence of an incumbent's mixed bundling on the probability of entry. An incumbent's mixed bundling included in variable profits leads to two opposing effects: demand effects and the retention of consumers. Demand effects can imply the size of demand for mixed bundling and lead to positive influences on the probability of entry by an entrant that prepares to provide mixed bundling.[7] When consumers are locked into mixed bundling offered by an incumbent, the telephone company would face lower variable profits due to increased competition (e.g., greater advertising costs for competing with an incumbent). However, variations in the telephone company's entry decisions are observed among markets in which consumers are locked into an incumbent's mixed bundling. This paper examines the hypothesis that these variations in the probability of DSL entry can be determined by the likelihood of switching suppliers in markets in which an incumbent offers mixed bundling.

Kiser (2002) and Giulietti et al. (2005) provide insights into the importance of measures of consumer preferences in consumers' decisions to switch suppliers by using household level data. In the market for the U.S. depository institutions, Kiser (2002) uses respondents' self-reported inconvenience of switching as a proxy for switching costs and finds that respondents with college degrees and high incomes appear more likely to report inconvenience in switching depository institutions.[8] In the U.K.

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[7] Qwest's press release demonstrates that Qwest has recognized the demand for mixed bundling and prepared to provide mixed bundling of TV, telephone, and high-speed Internet service in their service areas since the early 2000s. Qwest delivered early on its commitment to offer DSL high-speed Internet service in 72 markets in 14 western states by the end of 2000 and their DSL customers grew 105 percent to 360,000 customers over second quarter of 2000. Based on a strategic marketing alliance with DirecTV, they began to offer DirecTV digital satellite television services to residential customers across the western United States in 2004. Richard C. Notebaert, Qwest chairman and CEO, announced that this strategic marketing alliance would lead to Qwest's continued focus on expanding video and bundling for further growth.

[8] Households with very low incomes (less than $20,000) are also more likely to report inconvenience in switching depository institutions due to the following reasons: very low income households reside in neighborhoods with very few bank branches or they may have little benefit to switching due to low account balances. This paper focuses on

residential natural gas market, Giulietti et al. (2005) suggest that low income households are more likely to consider switching, while there is an inverted U-shaped relationship between household income and the probability that an individual household considers switching suppliers. They explain that a greater opportunity cost of time for higher income households is the main source of the likelihood of switching. This strong negative relationship between the consumers' decision to switch suppliers and measures of consumer preferences such as income and education can imply that the likelihood of switching decreases with income and education.

This paper further examines the influence of the likelihood of switching on the entrant's entry decisions in markets in which an incumbent offers mixed bundling. Unlike an individual household's decision to switch suppliers, the telephone company's decision of whether or not to enter the high-speed Internet market is influenced by market characteristics rather than characteristics of an individual household. By using average household income and average years of schooling, this paper can account for the effect of market characteristics on the telephone company's decision to enter a market. The likelihood of switching from an incumbent's mixed bundling to the telephone company's DSL service is measured by the interactions between an incumbent's firm characteristics (mixed bundling, *MXB*) and market characteristics (measures of consumer preferences such as income, *INCOME*, and education, *EDUC*). Therefore, this paper uses two interaction variables to measure the likelihood of switching in a market: $INCOME \times MXB$ and $EDUC \times MXB$.

Variable profits are also affected by other firm characteristics, market demand, and cost conditions. The entrant in this paper provides similar quality of services across markets due to its centrally controlled business operations and the DSL service, which is offered by its existing equipment. Firm characteristics of an incumbent can greatly influence the probability of entry, as post-entry competition can be determined by an incumbent's firm characteristics. It is likely that the entrant faces more intense competition with an incumbent that offers higher managerial or service quality. Demand for

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market characteristics instead of individual household characteristics. The likelihood of switching in markets with very low income may be different from that of very low income households.

high-speed Internet service is found to be higher for consumers who have higher incomes, are younger, or are more educated (Prieger, 2003; Savage and Waldman, 2004). Therefore, the variable profit per consumer[9] is given in Equation (3).

$$V(\boldsymbol{Z}, \alpha, \beta) = \alpha_0 MXB_{it} + \alpha_1 INCOME \times MXB_{it} + \alpha_2 EDUC \times MXB_{it} + \boldsymbol{X_{it}\beta}. \quad (3)$$

$\boldsymbol{X_{it}}$ includes firm characteristics of an incumbent, local demand, and cost conditions.

DSL entry incurs fixed costs of entry that include costs of personnel and equipment for DSL service. A longer distance between the entrant's headquarters and the geographical market to enter (*DIST*) implies higher costs of training and communication. Wire centers of the entrant provide telephone and DSL services. Longer distance between a wire center and a location of a consumer lowers the quality of DSL service. This limitation is overcome by a Digital Subscriber Line Access Multiplexer (DSLAM) that is placed in a remote terminal (*RT*). Fixed costs of entry are given in Equation (4).

$$F(\boldsymbol{W}, \gamma) = \gamma_0 + \gamma_1 DIST_{it} + \gamma_2 RT_{it}. \quad (4)$$

Based on market size, variable profits and costs, the DSL entry rule takes the reduced-form:

$$DSL\ Entry_{it} = \alpha_0 MXB_{it} + \alpha_1 INCOME_{it} \times MXB_{it} + \alpha_2 EDUC_{it} \times MXB_{it} + \boldsymbol{X_{it}\beta} + \boldsymbol{W_{it}\gamma} + \varepsilon_{it}. \ (5)$$

An unobserved error term is ε_{it}. The dependent variable, $DSL\ Entry_{it}$, takes the value one when Qwest enters the DSL service market and zero otherwise. As this paper aims to explain the influence of mixed bundling offered by an incumbent on the probability of DSL entry, the key variables of interests are MXB_{it}, $INCOME \times MXB_{it}$, and $EDUC \times MXB_{it}$. The next section describes the data used to test the DSL entry equation (5).

4. DATA

4.1. Sample

The sample contains the DSL entry decision of the telephone company in 2002, 2004, and 2006 in the western U.S. While Table 1 demonstrates a significant increase in the national shares of the DSL

[9] Monthly subscription fee for an incumbent's cable modem can be an important factor of variable profits. Due to insufficient variations in Warren Publishing, price competition will be examined as a robustness check in Section 5.

service during the period from 1999 to 2000, data sources for cable operators, such as Warren Publishing, have provided information on cable modem and telephone services since 2002. To examine the influence of mixed bundling on the DSL entry decision, this paper examines the DSL entry decision since 2002. The sample contains the biannual periods in 2002, 2004, and 2006, because the year-to-year changes appear to be insufficient to exploit an annual panel.[10] For these years, this paper examines the DSL entry decision in the 14 states of Arizona, Colorado, Idaho, Iowa, Minnesota, Montana, Nebraska, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming in which the telephone company is the most likely entrant into the high-speed Internet market.

DSL entry decisions are examined at the Census Block Group (CBG)[11] level in this paper. A CBG contains from 300 to 3,000 people. Consistent with Warren Publishing and a prior study on cable systems (Chen and Savage, 2011), one or two cable systems are found at the CBG level.[12] In markets with two cable systems, examining DSL entry decision at the CBG level requires identifying a dominant cable system, which contains a larger number of subscribers to basic service. Then, the telephone company's DSL entry decisions are matched with the corresponding service area of a dominant incumbent cable system.

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[10] Crawford and Yurukoglu (Forthcoming) point out persistent non-updating of entries in the Warren Publishing's *Television and Cable Factbook*. For example, there are rare changes in yearly entries on the number of subscribers to basic cable TV service, monthly subscription price to basic cable TV service, and monthly subscription price to cable modem service during the sample period.

[11] To examine DSL entry decisions, it is critical to define a geographic market, which allows us to identify an incumbent cable system and find whether it offers mixed bundling. Geographical markets in prior studies on the DSL deployment are postal service codes (Prieger, 2003; Xiao and Orazem, 2005), counties (Gillett and Lehr, 1999), wire centers (Gabel and Kwan, 2001), and census block groups (Molnar and Savage, 2012).

A wire center has the switching machine that connects a customer's line to another customer who is served by the same (or a different) wire center. A wire center does not well account for the influence of mixed bundling on the probability of DSL entry. As a wire center can serve multiple neighboring cities in low density areas, it is complicated to identify a dominant incumbent cable system at the wire center level. Data on the telephone company demonstrates that DSL deployment decisions are made at the wire center level. Based on discussions with industry people, DSL entry decisions are made at the aggregate level (e.g., at the city level), but actual rollout is implemented at much finer level over time. Examining the probability of DSL entry at the CBG level can account for the staged rollout of DSL entry.

[12] A prior study on cable systems (Chen and Savage, 2011) also demonstrates one or two cable systems in a local market.

To examine the DSL entry decisions of Qwest in markets in which an incumbent cable system is present, data sources on cable systems are merged with that of the telephone company. Data on cable systems are sourced from Warren Publishing which does not have an integrated cable area (ICA) identifier. Direct Group's (2008) "MEDIAPRINTS Block Group Translation Table" matches each cable system with both ICA and CBG identifiers. Merging these two data sources identifies cable systems at the CBG level. Data on the telephone company contain the timing of DSL deployment from 1999 to 2006 for Common Language Location Identification (CLLI) codes[13] that identify each wire center. An additional data source on the telephone company, Claritas (2003), provides information on both CLLI codes and CBG. By merging these two datasets on the telephone company, the timing of the telephone company's DSL deployment of a wire center in a CBG is identified. As CBG identifiers are contained in data sources on both cable systems and the telephone company, the telephone company data is matched with data on cable systems by using CBG identifiers.

To control for demand conditions, the dataset is merged with the American Community Survey (ACS), which reports annual estimates of demand variables at the county level. Since the ACS does not provide annual estimates of education for North Dakota, South Dakota and Wyoming in 2002 and 2004, education data in 2000 and 2005 are substituted for that of 2002 and 2004. State reports on high-speed Internet access are also used to update information on the provision of cable modem service in cities in Iowa and counties in Nebraska as of 2006 (Iowa Utilities Board, 2006; Nebraska Public Service of Commission, 2007). In addition, fixed costs of DSL entry at the CBG level are sourced from the FCC's Hybrid Cost Proxy Model (HCPM) workfiles.[14] Appendix A details the merge between the sample and the FCC's HCPM workfiles and the process of estimating fixed costs of DSL service offered by the telephone company.

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[13] More detailed information about CLLI is available at www.ntca.org.

[14] The FCC divides regions served by large carriers into roughly 12,493 geographic areas based on the current location of wire centers that telephone companies have. At each wire center, the model estimates the forward-looking economic costs of the various components used to provide basic local telephone service: loop, switching, signaling and transport, etc. Based on the differences in local conditions, population density, and other factors, the model estimates average costs of providing local service in each wire center (Wimmer and Rosston, 2005).

4.2. Summary statistics and variables

The sample is a balanced panel and consists of 73,920 CBGs in 1,276 cities of 14 states over the sample period. In small cities, this initial sample contains observations that have missing values in years of schooling[15] and rare occurrences of exits of cable systems.[16] Eliminating these observations reduces the sample size to 53,346 CBG in 275 cities of 14 states in 2002, 2004, and 2006. However, this reduced sample can account for the DSL entry decisions by the telephone company, considering the telephone company's tendency to serve large urban markets. In Figure 1, the DSL entry rate of the telephone company has shown a similar pattern before and after the eliminations of observations with missing values and rare exits of cable systems. Although there is a difference in the magnitude of the DSL entry rate, the reduced sample after the elimination can still closely capture the trend in DSL entry. In both initial and reduced samples, DSL entry rate has increased over the sample period and the growth of the DSL entry rate was higher from 2002 to 2004. Therefore, this paper uses the reduced sample to estimate the DSL entry equation (5) in Section 3.

Table 2 provides descriptive statistics on the DSL entry, mixed bundling, and measures of consumer preferences such as income and education in the sample. Over the sample period, the telephone company enters the high-speed Internet market in 42,941 CBGs. An incumbent provides mixed bundling in more than 30 percent of the markets in the sample. The average household income in a market is $47,860 and the average years of schooling is about thirteen years (i.e., about one year of college education) for people over 25 years old.

Tables 3 and 4 describe variables and descriptive statistics in the DSL entry equation. The key variables of interest are mixed bundling offered by an incumbent cable system (*MXB*) and the interplay between measures of consumer preferences and mixed bundling. As a follower in the high-speed Internet market, the probability of the DSL entry by the telephone company is assumed to depend on the likelihood of switching away from an incumbent in this paper. The likelihood of switching can be

[15] Census Bureau reports information on the average years of education in relatively large cities in the early 2000s.
[16] Very few cable systems are not present in 2002 or bought by other cable companies over the sample period.

influenced by consumer loyalty and opportunity costs of searching alternative service providers. Switching from an incumbent's bundled service to the entrant's DSL service requires time, effort, and costs of learning the entrant's service, and compatibility to existing equipment. It is possible that consumers who are locked into an incumbent's mixed bundling in some markets are more (less) likely to switch than their counterparts in other markets. The likelihood of switching from an incumbent to the telephone company's DSL service is measured by the interplay between measures of consumer preferences and mixed bundling: *INCOME×MXB* and *EDUC×MXB*. In markets with higher median income, consumers would not switch a service provider because of subscription fees for cable modem service. When the opportunity costs of time needed to switch a service provider increase with income (*INCOME*) or education level (*EDUC*), the likelihood of switching is low in markets with higher income or more years of schooling. The probability of DSL entry would decrease with the median income or median number of years of schooling a market in which mixed bundling is offered by an incumbent. The coefficients on *INCOME×MXB* and *EDUC×MXB* are expected to be negative.

Along with *INCOME×MXB* and *EDUC×MXB*, which are used to measure the likelihood of switching, *MXB* can estimate the demand effect. The telephone company was prepared to offer mixed bundling before the DSL entry. An incumbent's offering mixed bundling can indicate the demand for mixed bundling and can, in turn, increase the probability of entry by the telephone company that also prepares for mixed bundling service. The coefficient on *MXB* is expected to be positive.

Variable profits of the entrant are also influenced by other firm characteristics of an incumbent and demand conditions: a multi-system operator (MSO; *MSO*), years of employment of managers (*TENURE_LONG* and *TENURE_SHORT*) and complaints on an incumbent's service (*COMPLAINTS*). A multi-system operator (MSO) refers to a cable operator which acquires more than one cable system and brings them under the umbrella of a single corporate entity (Chen and Savage, 2011). As a MSO may have lower cost deals from program suppliers, it can have a relative cost advantage over non-MSOs

(Chipty, 1995; Singer, 2003).[17] In contrast to the cost advantages of a MSO, Emmons and Prager (1997) find a positive relationship between the number of cable systems owned by a MSO and the average monthly subscription fees for subscription TV. Higher subscription fees charged by an incumbent MSO cable system can imply less intense price competition compared to the competition with those non-MSO cable systems. Thus, the influence of a MSO cable system on the probability of the DSL entry depends on the net effect of cost advantages and the relatively higher monthly rate of a MSO.

The quality of service offered by an incumbent cable system can influence the DSL entry by two channels: price and consumer satisfaction. If low quality service results from low subscription fees that an incumbent charges, more intense price competition can reduce the probability of the DSL entry (Linnemer, 2002). On the contrary, the low quality service can imply that consumer dissatisfaction with an incumbent's service may increase the likelihood of switching away from an incumbent (Giulietti et al., 2005; Wilson and Price, 2010).

This paper measures service quality in two ways: managerial quality of an incumbent (*TENURE_SHORT* and *TENURE_LONG*) and consumers' complaints about an incumbent's service (*COMPLAINTS*). Regarding the importance of managerial quality, Goldfarb and Xiao (2011) suggest more experienced managers tend to correctly conjecture competitor behavior than do less experienced ones. As experienced managers in an incumbent cable system are able to better understand consumers and competition in a market, the presence of these experienced managers may lead the telephone company to expect more intense post-entry competition. Therefore, this paper expects a negative relationship between the experience of managers in an incumbent and the probability of DSL entry. To incorporate any possible nonlinear effect of managerial experience on DSL entry, more years of managerial experience are distinguished from the managerial experience which is obtained in the more recent time period. *TENURE_LONG* is a qualitative variable that equals one when a manager had

[17] Emmons and Prager (1997) also suggest that large MSOs may not compete very aggressively against each other, for fear of retaliation in other markets they serve. Since little is known about the entry deterrence of incumbent cable systems which face DSL entry offered by telephone companies, it is an empirical question that a MSO reduces the probability of DSL entry of the telephone company.

consecutive employment from 1999 to 2006 and is an indicator for traditional managers. *TENURE_SHORT* equals one when a manager had consecutive employment from only 2002 to 2006 and is an indicator for relatively new managers. Coefficients on *TENURE_SHORT* and *TENURE_LONG* are expected to be negative.

Consumers' complaints on cable systems (*COMPLAINTS*) also measure service quality of an incumbent. As in Table 5, FCC data provides consumers' complaints (*COMPLAINTS*) on billing and rates, reliability of cable modem and service quality of personnel in cable companies. While the only weakness of this data is that the number of consumer complaints is aggregated to the national level, a large number of complaints may exhibit low brand loyalty or a large market share. Therefore, the coefficient on *COMPLAINTS* depends on the relative size of these two opposing effects.

Demand conditions[18] include the number of establishments (*EST*), median household income (*INCOME*), median age of households (*AGE*), average number of years of schooling for the population over 25 years of age (*EDUC*), and the number of houses (*HOUSING*). The number of establishments (*EST*) accounts for the activity of local businesses. While changes in local businesses are not directly related to residential DSL entry by the telephone company, a large number of establishments may imply that the areas are not residential locations which in turn decrease the residential DSL service. Prior studies find that high-speed Internet users are more likely to be wealthier, younger, or more educated households (Rappoport et al., 2002; Prieger, 2003; Savage and Waldman, 2004; Chaudhuri et al., 2005; Goldfarb and Prince, 2008; and Xiao and Orazem, 2011). In addition, the number of housing units (*HOUSING*) is also included to measure the demand size for high-speed Internet access. A single high-speed Internet service provider serves multiple occupants in the same household and earns the same

[18] Prior studies also examine the role of gender or race in the demand for high-speed Internet but produce inconsistent results. Gender does not play any significant role in the usage of Internet in Savage and Waldman (2004) and Goldfarb and Prince (2008), while Rapporport et al. (2002) suggest that being a male is more likely to subscribe to high-speed Internet. Race is important to explain digital divide in Fairlie (2004) and Stanton (2004) suggests that blacks have lower demand for high-speed Internet demand. However, Leigh (2003) finds no significance and Prieger and Hu (2008) discuss inconsistent findings in the importance of race in the previous literature.

amount of monthly subscription fees for the high-speed Internet service regardless of the number of occupants in the same household. For a given population, an increase in housing units implies that the average household size in a market rises. This, in turn, may decrease the profitability of Internet service providers. On the contrary, Savage and Waldman (2005) find that high-speed Internet access is more likely in households with two or more occupants than in household with a single occupant. The influence of *HOUSING* on the probability of DSL entry is an empirical question. As the probability of DSL entry increases with the market size which contains a large demand for high-speed Internet service, the probability of DSL entry increases with the population (*POP*).

In consideration of cost conditions, fixed costs of entry are measured by two variables: a remote terminal (*RT*) and the distance between the headquarters of the telephone company and a geographical market it wishes to enter (*DIST*). A remote terminal is the switching or routing equipment that is located outside of a wire center. Before DSL entry, the *RT* must be already installed, so that it does not have to incur additional fixed costs to serve more consumers. All other things equal, markets with more *RT* are likely to be able to serve more consumers with high quality DSL because they can put DSLAM closer to the subscriber and thus eliminate the distance limitation of DSL.[19] Therefore, *RT* will likely increase the probability of DSL entry. An additional cost control for DSL deployment is measured by *DIST*. The entrant's headquarters make DSL service territory entry decisions. It is likely that the entrant's transportation and communication costs increase with the distance between its headquarters and the new potential geographical market.[20]

To account for different environments in high-speed Internet access across states, state indicator variables are included. These variables will remove the impact of any factor, observed or not, that varies

[19] Technical descriptions on remote terminals are available at http://www.dslreports.com.

[20] Felici and Pagnini (2008) explain how the entry decisions are influenced by the influence of the distance between headquarters and the new potential geographical market.

among states but not within a state such as the state regulatory environment and average demand and supply conditions.[21]

5. ESTIMATION RESULTS

5.1. Results

The reduced-form model of the DSL entry equation (5) in Section 3 and data described in Section 4 are used to examine the influence of product bundling on DSL entry decisions of Qwest. This section discusses the direction and significance of the estimation results. The dependent variable is the telephone company's DSL entry decisions which take either zero or one. While probit and logit model restrict the support of the probability space to the unit interval, these models introduce problems which can potentially lead to biased estimates of the marginal effects. The advantage of the linear probability model (LPM) over these discrete choice models is that it is more amenable to computation of the marginal effects. The linear probability model implies that a unit increase in any of the right hand side variables has the same effect on the probability of the positive outcome, regardless of the initial value of the variable. The model can yield good estimates near the center of the distribution of the right hand side variables. It is also advantageous, when independent variables are discrete (Wooldridge, 2002).[22] The Hausman test is used to compare the random effects estimates with that of the fixed effects model and determine whether regressors are correlated with unobserved heterogeneity. Based on a large Hausman test statistic, the fixed effects model is used to account for the telephone company's DSL entry decisions.

Models (1) to (5) in Table 6 demonstrate estimation results in the DSL entry equation (5): without any control for the likelihood of switching in model (1); with the inclusion of a single interaction term to control for the likelihood of switching in models (2) and (3); with the inclusion of two interaction terms to

[21] Prieger (2003) discusses the importance of state dummies in examining high-speed Internet penetration rates.
[22] Goetz and Shapiro (2012) explain advantages of using LPM over binary logit and probit models and apply LPM to examine airlines' codesharing.

control for the likelihood of switching in model (4); with the additional control for year effects to control for unobserved factors that affect the DSL entry over time in model (5).

Without any consideration for the likelihood of switching, model (1) shows the influence of demand and cost conditions on the probability of DSL entry. The estimated coefficient on *MXB* is negative (-0.0127), significant at the one percent level, and supports the prediction from the economic theory that an incumbent's mixed bundling can decrease potential entry (Whinston, 1990; Nalebuff, 2004). Specifically, this estimate may indicate that mixed bundling offered by an incumbent decreases the probability of DSL entry by 1.27 percentage points. However, *MXB* contains two opposing effects on the DSL entry: demand for mixed bundling and the retention of consumers. Two opposing effects in mixed bundling are separately measured in models (2)–(5). Positive and significant coefficients on *MXB* imply that *MXB* captures the demand for mixed bundling in a market and increases the probability of DSL entry by the telephone company which prepares to provide mixed bundling in the near future.

It is possible that consumers who are locked into an incumbent's mixed bundling in some markets are more (or less) likely to switch than their counterparts in other markets. This difference in the likelihood of switching is measured by $INCOME \times MXB$ and $EDUC \times MXB$ in models (2)–(5). The interaction terms enter separately into model (2) and (3). The estimated coefficient on $INCOME \times MXB$ is negative (-0.004), significant at the one percent level, and supports the prediction that high-income markets would stay in an incumbent's mixed bundling because of the high opportunity costs of time. When the median income increases by $1,000, the probability of DSL entry is predicted to fall by 0.4 percentage points in a market in which an incumbent offers mixed bundling. In model (3), the estimated coefficient on $EDUC \times MXB$ is significant at the one percent level and indicates that an additional year of schooling for the market population decreases the probability of DSL entry by 9.9 percentage points in a market with mixed bundling offered by an incumbent. Model (4) includes two interaction terms jointly and obtains similar results in models (2) and (3). Year dummies in model (5) account for time-specific effects such as the nationwide increase in high-speed Internet users. While $INCOME \times MXB$ loses its significance in model (5), the coefficient on $EDUC \times MXB$ is still negative and statistically significant at the five percent level.

The overall effect of mixed bundling offered by an incumbent on the probability of DSL entry is estimated by:

$$\partial DSL\_Entry / \partial MXB = -0.9383 + 0.0001 \times INCOME - 0.0256 \times EDUC.$$

At the mean value for *INCOME* and *EDUC*, the estimate of overall effect ($\partial DSL\_Entry / \partial MXB$) is negative (-0.0189), statistically significant at the one percent level. This implies that mixed bundling offered by an incumbent can decrease the probability of DSL entry by 1.89 percent points. A negative overall effect suggests that the demand effects of an incumbent's mixed bundling is outweighed by the negative effect resulting from the retention of consumers. Overall, an incumbent's mixed bundling can decrease the probability of DSL entry by the telephone company. An interesting implication of this effect is obtained by evaluating $\partial DSL\_Entry / \partial MXB$ at the sample minimum for *EDUC*. When evaluated at the minimum value (which is about eleven years of schooling), the probability of DSL entry is about five percent higher in markets with an incumbent's mixed bundling than its counterpart markets in which an incumbent does not offer mixed bundling. This implies that the probability of DSL entry would be lower in markets with more years of schooling where an incumbent offers mixed bundling, due to their lower likelihood of switching. As other possible factors may influence the telephone company's entry decisions, the next section runs additional tests.

5.2. Robustness Check

To check the sensitivity of estimated results on the influence of mixed bundling on the probability of DSL entry, this section includes other factors[23] that can affect DSL entry decisions: the number of

[23] Economies of scale might be another factor to influence the probability of DSL entry. When a census block group is a part of a populated county, the incremental cost of an additional line is lower than that of a less populated county. To account for economies of scale, the reduced-form models (1)–(5) in Table 6 are estimated by the number of population at the county level (a proxy for economies of scale) and demand variables (income, education, age, housing, and population) at the census block group level. This model with economies of scale is also estimated in

firms which provides either wireline or wireless service in a market (*COMPETITION*)[24] and the average price of cable modem service offered by an incumbent (*PRICE*). Following Bresnahan and Reiss (1991) and Berry (1992), an increase in the number of firms (*COMPETITORS*) would lead to intense competition in the market[25] and, in turn, decrease the probability of DSL entry.

Price can also affect the probability of DSL entry. Information on the average monthly subscription fee for high-speed Internet service offered by *COMPETITORS* in a market over the sample period was not available. While the average monthly subscription fees of cable modem service offered by an incumbent (*PRICE*) is available, due to many observations with missing values on *PRICE*, the influence of price competition is examined only as a robustness check. *PRICE* may still contain two opposing impacts on the probability of DSL entry: price competition and price as a signal of quality. High *PRICE* can lead the entrant to expect less intense price competition in a market and have a positive relationship with the probability of DSL entry. However, this can also imply a signal for high quality that can decrease the probability of DSL entry. A more precise estimation may require quality-adjusted price indexes for an incumbent's cable modem service. Calculating this index is beyond the scope of this study. The influence of *PRICE* on the probability of DSL entry remains an open empirical question.

To examine the impact of *COMPETITORS* and *PRICE* on the probability of entry, observations with missing values in one of these two variables are excluded. With this reduced sample, estimates in model (1) of Table 7 are obtained from the same specification as model (5) in Table 6; adding *COMPETITORS*; adding both *COMPETITORS* and *PRICE*. While there is no qualitative difference

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panel data and cross-sectional data (i.e., in 2002, 2004, and 2006, separately). In both panel and cross-sectional data, estimation results are consistent with that of Table 6.

[24] The FCC reports the number of facilities-based firms with 250 or more terrestrial high-speed Internet lines or wireless high-speed channels at the zip-code level. However, the data masks data for zip codes with less than four providers. It is not possible to observe the exact number of high-speed Internet service providers in markets with less than four providers. In addition, a census block group may contain more than one zip code (Grubesic, 2008, for detail discussions on zip code level data use). High-speed Internet service providers in a zip code are likely to provide their services in more than one zip code within the same city. To resolve the compatibility between zip code and census block group, this study opts for the estimated average of the number of Internet service providers at the city level, i.e., *COMPETITORS*. While models (1)–(3) in Table 7 are also estimated by minimum and maximum values of *COMPETITORS* and *PRICE*, consistent results are obtained.

[25] Since an incumbent cable system and the telephone company are two dominant firms in the high-speed Internet market, the size of high-speed Internet service providers should be considered for a more precise analysis.

between Table 6 and 7, a \$1,000 increase in median income decreases the probability of DSL entry by 0.08 percentage points in a market in which an incumbent offers mixed bundling. With the inclusion of the number of competitors in model (2) and an additional control for monthly subscription fees of cable modem service in model (3), *INCOME×MXB* is still negative, statistically significant at the one percent level. *EDUC×MXB* is not statistically significant in models (2) and (3). However, the z-statistic for *EDUC×MXB* in model (3) is 1.577, which is marginally significant. Consistent with economic theory, model (2) demonstrates that an additional high-speed Internet provider in a market decreases the probability of DSL entry by 1.4 percentage points. In model (3), a one dollar increase in the monthly subscription fee of cable modem decreases the probability of the DSL entry by 0.27 percentage points. Along with models (1)–(5) in Table 6, models (1)–(3) in Table 7 are also estimated by a discrete choice model and estimation results are demonstrated in Appendix B.

While DSL entry is determined by market size, variable profits, and fixed costs, Tables 6 and 7 present consistent results in market size, other remaining factors in variable profits, and fixed costs. The probability of DSL entry increases with population (*POP*) due to large market size. The probability of DSL entry is lower in markets in which an incumbent is an MSO cable system than in markets with a non-MSO incumbent cable system. A negative significant coefficient on *MSO* implies that cost advantage of a MSO cable system outweighs its higher price and decreases the probability of DSL entry. Quality of service can be measured by managerial and consumer complaints. Eisenhardt (1999) suggests the entrant can expect more intense competition with newer managers who are more likely to bring in fresh ideas about competition and exploiting the latest technology. Traditional managers might tend to rely on their expertise from the industry, but might be slower in adapting to recent industry changes than newer managers. Negative and significant coefficients on *TENURE_SHORT* and *TENURE_LONG* may support the possibility that experienced managers employed by an incumbent firm are better able to anticipate competitor behavior in a market, thereby reducing the probability of DSL entry. A t-test result reveals the existence of nonlinear effect in managerial quality. The probability of DSL entry is lower in markets with the presence of an incumbent's manager who has been more recently employed and has accumulated more recent knowledge about the market than in markets with the traditional managers. Since data on complaints about an incumbent show the number of complaints (*COMPLAINTS*) mostly for the top ten largest cable operators, *COMPLAINTS* captures both an incumbent's firm size and the service quality of an incumbent. A positive coefficient on *COMPLAINTS* indicates the size effect outweighs the quality effect. The probability of DSL entry does not increase with the number of complaints on a big incumbent.[26]

Regarding demand conditions, the probability of DSL decreases with the number of local businesses (*EST*), as this paper examines residential DSL service. This increases with median income (*INCOME*) and average years of schooling (*EDUC*). A coefficient on *HOUSING* is negative, statistically significant at the one percent level. Given the population, an increase in housing (*HOUSING*) indicates smaller housing size. As high-speed Internet access is more likely in households with two or more occupants (Savage and Waldman, 2005), smaller housing size may imply lower demand for high-speed Internet access and decreases the probability of DSL entry.

In terms of fixed costs of entry, the fixed effects linear probability model considers only variables that change over time. There is no variation across years in the distance between headquarters of the entrant and the geographical market to entry (*DIST*), which is dropped in the regression. As the presence of a remote terminal (*RT*) improves the quality of DSL service, this increases the probability of DSL entry. A positive, significant coefficient on *RT* is consistent with the prior expectation in Section 4.

6. CONCLUSION

This paper conducts an empirical study of how mixed bundling offered by an incumbent influences the probability of entry by a potential mixed bundling provider. While prior studies focus on

[26] To account for the size of a cable system, an alternative measures for *COMPLAINTS* is used, i.e., the average number of complaints (calculated by "the number of complaints divided by the number of subscribers to basic cable TV service"). No qualitative change in estimation results is found.

the product bundling as an entry deterring strategy, there are relatively fewer discussions about the effects of product bundling on the entry of a multiproduct supplier. By using a unique data set of residential DSL entry decisions by a dominant telephone company in the western U.S., empirical findings in this paper present two opposing effects of an incumbent's mixed bundling on the probability of entry. The provision of an incumbent's mixed bundling itself can indicate the demand for mixed bundling service and increases the probability of DSL entry, as the telephone company prepares for offering mixed bundling. The probability of DSL entry decreases with income or years of schooling in a market in which an incumbent cable system offers mixed bundling due to higher opportunity costs of time incurred by switching service providers.

These findings suggest interesting policy implications in enhancing high-speed internet access in the U.S. The federal government spent nearly ten billion dollars to support the connectivity of communications and improve broadband infrastructure in 2010.[27] Distaso, Lupi, and Manenti (2006) find that inter-platform competition between DSL and cable modem service is the main driver for high-speed Internet penetration at the national level. Therefore, inter-platform competition led by the DSL entry may increase nationwide high-speed Internet access. Pew International and American Life Project (2009) demonstrate that subscription fees for high-speed Internet service is still high and many Internet service providers do not make much investment. With increased competition led by the DSL entry, it is likely that an incumbent cable system has an incentive to lower monthly subscription fees to prepare for price competition or provide better quality of high-speed Internet service to maintain its market share. Consumers, in turn, can gain from an increase in inter-platform competition.

Findings in this paper shed some light on achieving Next Generation Network (NGN) [28] investment, which increases data transmission speed and enables new applications such as high definition,

[27] See Broadband National Plan in www.broadband.gov for a more detailed discussion about the federal government's plan to increase the high-speed Internet access.
[28] Next generation networks refer to upgrades to existing telecommunications and information services that implement cutting edge technological advances. These networks provide conduits for delivering high definition,

interactive TV. While the American Recovery and Reinvestment Act of 2009 earmarked $7.2 billion for NGN investment, it is uncertain when and to what extent it will be deployed in the market (Nitsche and Wietahus, 2011). Infrastructure for product bundling can be used to provide higher levels of telecommunications service, and increased competition between multiproduct suppliers can provide cable systems and telephone companies with incentives to deploy these faster and higher levels of services in NGN. By examining the DSL entry decisions by the telephone company, which has prepared to provide mixed bundling, this paper suggests that encouraging DSL entry by a potential mixed bundling provider can result in an increase in the high-speed Internet access and the achievement of faster and higher level of telecommunications services.

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multi-media content. For example, next generation high definition television may offer a three dimensional format in these networks (Frieden, 2010).

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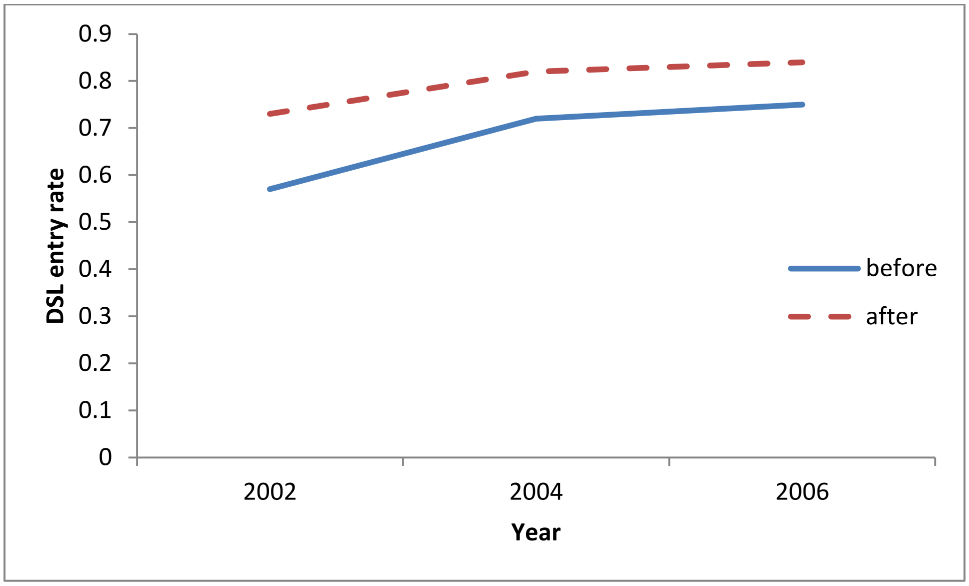
Figure 1. DSL DEPLOYMENT RATE OF QWEST



Note:
"before" is the data based on 73,920 CBGs which include observations with missing values and rare observations of exits.
"after" is the data based on 53,346 CBGs which exclude these observations.

Table 1. RESIDENTIAL HIGH-SPEED INTERNET LINES IN U.S.
(Over 200 kbps in at least one direction)

Technology	1999 Dec	2000 Dec	2001 Dec	2002 Dec	2003 Dec	2004 Dec	2005 Dec	2006 Dec
ADSL	291,757 (0.16)	1,594,879 (0.30)	3,615,989 (0.32)	5,529,421 (0.31)	8,909,027 (0.34)	13,119,326 (0.37)	17,370,508 (0.39)	22,773,133 (0.39)
SDSL and Traditional Wireline	-	176,520 (0.03)	139,660 (0.01)	213,489 (0.01)	289,764 (0.01)	419,215 (0.01)	129,444 (0.00)	117,469 (0.00)
Cable Modem	1,402,394 (0.78)	3,294,546 (0.63)	7,050,709 (0.64)	11,342,512 (0.65)	16,416,364 (0.63)	21,270,158 (0.60)	25,714,461 (0.58)	31,230,519 (0.53)
Fiber	1,023 (0.00)	1,994 (0.00)	4,139 (0.00)	14,692 (0.00)	19,830 (0.00)	34,959 (0.00)	213,479 (0.00)	758,137 (0.01)
Satellite and Wireless	50,189 (0.02)	102,432 (0.01)	194,897 (0.01)	256,978 (0.01)	341,864 (0.01)	422,623 (0.01)	532,704 (0.01)	3,359,952 (0.05)
Power line and others	-	-	-	-	-	-	4,550 (0.00)	4,711 (0.00)
Total lines	**1,792,219**	**5,170,371**	**11,005,396**	**17,356,912**	**25,976,850**	**35,266,281**	**43,965,147**	**58,243,921**

Source: FCC (2007)

Note:

Market shares in parenthesis.

Table 2. CABLE SYSTEMS IN 14 STATES

State / U.S.	No. of cable systems	No. of cable systems with DSL entry	Mean MXB	Mean Income	Mean Educ-ation
Arizona	7,791	6,875	.54	46,383.37	12.98
Colorado	7,401	7,127	.18	46,946.04	13.52
Idaho	1,422	1,016	.00	43,906.60	13.36
Iowa	3,018	2,366	.17	46,372.90	13.52
Minnesota	6,699	5,738	.40	52,020.33	13.82
Montana	975	730	.09	39,352.25	13.60
Nebraska	2,430	1,729	.72	47,638.83	13.68
New Mexico	2,244	1,985	.00	41,637.79	13.13
North Dakota	615	546	.00	42,047.66	13.78
Oregon	5,742	4,166	.11	44,275.25	13.51
South Dakota	387	290	.00	45,797.14	13.44
Utah	2,817	2,772	.57	49,063.49	13.54
Washington	11,514	7,316	.36	51,841.96	13.63
Wyoming	291	285	.14	44,546.67	13.33
Total	**53,346**	**42,941**	**.32***	**47,860.26***	**13.49***

Note:
* indicate the sample mean.

Table 3. DSL ENTRY EQUATION VARIABLES

Variable	Description and data source
DSL Entry	1 if the telephone company provides its DSL service in a consumer block group (CBG) and 0 otherwise. Source: the telephone company's confidential data (1998 - 2006).
Market Size	
POP	The number of population at the county level (in 1,000). Source: Census Bureau (2002, 2004, 2006).
Variable Profits	
Firm Characteristics	
MXB	1 if a cable system provides mixed bundling, 0 otherwise. Source: Warren Publishing (2002, 2004, 2006).
INCOME × MXB	The interaction between median household income and mixed bundling provided by a cable system. Source: Census Bureau (2002, 2004, 2006) and Warren Publishing (2002, 2004, 2006).
EDUC × MXB	The interaction between median number of years of schooling for the population over 25 years of age and mixed bundling provided by a cable system. Source: Census Bureau (2000, 2005, 2006) and Warren Publishing (2002, 2004, 2006).
MSO	1 if a cable system is owned by a multiple-system operator, 0 otherwise. Source: Warren Publishing (2002, 2004, 2006).
COMPLAINTS	Complaints of consumers on billing, cable modem connection, service quality of cable operators reported to FCC. Source: the FCC (2003, 2004, 2006).
TENURE_SHORT	1 if a general manager has been employed by the same cable system from 2002 to 2006, 0 otherwise. Source: Warren Publishing (2002, 2004 and 2006).
TENURE_LONG	1 if a general manager has been employed by the same cable system from 1999 to 2006, 0 otherwise. Source: Warren Publishing (1999, 2002, 2004 and 2006)
COMPETITORS	The estimated number of Internet service providers at the city level. Source: the FCC (Dec 2002, Dec 2004, Dec 2006).
PRICE	The average monthly subscription fee for cable modem service. Source: Warren Publishing (2002, 2004, 2006).
Demand	
INCOME	Median household income at the county level (in $1,000). Source: Census Bureau (2002, 2004, 2006).

EDUC	Median number of years of schooling calculated from the data on the population over 25 years of age in each educational category. Source: Census Bureau (2000, 2005, 2006).
EST	The number of business establishment at the zip code level (in 100). Source: Census Bureau (2002, 2004, 2006).
AGE	Median age of the population at the county level. Source: Census Bureau (2002, 2004, 2006).
HOUSING	The number of housing units at the county level (in 1,000). Source: Census Bureau (2002, 2004, 2006).
Fixed Costs	
DIST	The distance between the headquarters of the telephone company and a wire center. It is measure by the geographical distance between the city where the telephone company's headquarter is located and a city where their wire center is located. The minimum distance is taken in a CBG when more than one wire center exists. Source: www.telcodata.us (to identify the location of a wire center); www.geobytes.com and www.symsys.com (to measure the distance between two cities) (2011).
RT	The estimated number of remote terminals that the telephone company contains to provide telephone and DSL service. Source: the FCC Hybrid Cost Proxy Model (2000).

Table 4. DSL ENTRY EQUATION SUMMARY STATISTICS

Variable	Obs.	Mean	S.D.	Min	Max
DSL_ENTRY	53,346	.80	.39	.00	1.00
Market Size					
POP	53,346	931.40	1,057.31	7.09	3,776.11
Variable Profits					
Firm Characteristics					
MXB	53,346	.32	.46	.00	1.00
INCOME × MXB	53,346	16.10	23.63	.00	93.27
EDUC × MXB	53,346	4.35	6.32	.00	14.92
MSO	53,346	.98	0.11	.00	1.00
COMPLAINTS	53,346	41.99	53.20	.00	149.00
TENURE_SHORT	53,346	.27	.44	.00	1.00
TENURE_LONG	53,346	.27	.44	.00	1.00
COMPETITORS	49,638	9.11	3.05	2.00	14.67
PRICE	48,110	41.78	8.53	19.95	150.00
Demand					
INCOME	53,346	47.86	7.81	24.23	100.77
EDUC	53,346	13.49	.53	10.99	15.09
EST	53,346	261.86	260.26	5.18	877.90
AGE	53,346	34.58	3.01	23.10	47.60
HOUSING	53,346	382.49	399.29	286.00	1,496.12
Fixed Costs					
DISTANCE	53,346	623.82	320.54	.00	1,136.00
RT	53,346	2.37	.94	1.34	6.28

Note:
Variables are described in Table 3.

Table 5. AN EXAMPLE OF CONSUMER COMPLAINTS FORM

57 (the total number of complaints)		XXXX (the name of the firm)
3	Billing Rates	
2		Billing Dispute
		2005 June
1		Consumer Rate Issue
		2005 April
37	Cable Internet Modem Service	
10		No Sub-Categories Available
		2005 May Jul Aug Oct Nov
27		No Sub-Category Assigned
		2005 Apr May Jun Jul Aug Sep Oct Nov
4	Connections to Cable Systems	
		No Sub-Category Assigned
		2005 May Aug Oct
3	Other	
		Other
		2005 Mar Jun Jul
10	Service Issues	
1		Digital Service
		2005 Feb
3		Service Availability
		2003 Aug
5		Service Treatment
		2005 Jun Aug Nov
1		Signal Quality
		2005 Sep

Table 6. ESTIMATES IN THE DSL ENTRY EQUATION

	(1)	(2)	(3)	(4)	(5)
VARIABLES	DSL_ENTRY	DSL_ENTRY	DSL_ENTRY	DSL_ENTRY	DSL_ENTRY
Variable Profits					
Firm Characteristics					
MXB	-0.0127***	0.2047***	1.3363***	0.9492***	0.3279**
	(0.003)	(0.016)	(0.115)	(0.123)	(0.139)
INCOME × MXB		-0.0044***		-0.0029***	0.0001
		(0.000)		(0.000)	(0.000)
EDUC × MXB			-0.0990***	-0.0601***	-0.0256**
			(0.008)	(0.009)	(0.010)
MSO	-0.0288**	-0.0493***	-0.0386***	-0.0483***	-0.0343***
	(0.012)	(0.012)	(0.011)	(0.012)	(0.012)
TENURE_SHORT	-0.1034***	-0.0985***	-0.0976***	-0.0967***	-0.0769***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
TENURE_LONG	-0.0475***	-0.0390***	-0.0405***	-0.0376***	-0.0187***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
COMPLAINTS	-0.0008***	-0.0008***	-0.0008***	-0.0008***	-0.0009***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Demand					
INCOME	0.0234***	0.0270***	0.0259***	0.0273***	0.0166***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
EDUC	0.2885***	0.2591***	0.2810***	0.2646***	0.0838***
	(0.010)	(0.010)	(0.010)	(0.010)	(0.015)
EST	-0.0054***	-0.0048***	-0.0043***	-0.0043***	-0.0044***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
AGE	0.0252***	0.0243***	0.0215***	0.0224***	0.0042
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
HOUSING	-0.0038***	-0.0029***	-0.0035***	-0.0030***	-0.0045***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Market Size					
POP	0.0023***	0.0018***	0.0020***	0.0018***	0.0022***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Fixed Costs					
RT	0.1908***	0.1870***	0.1868***	0.1859***	0.2188***
	(0.014)	(0.014)	(0.014)	(0.014)	(0.015)
Year Fixed Effect	No	No	No	No	Yes
Constant	-4.6942***	-4.5067***	-4.7207***	-4.5866***	-0.9383***
	(0.189)	(0.188)	(0.188)	(0.188)	(0.293)
Observations	53,346	53,346	53,346	53,346	53,346
R-squared	0.1546	0.1583	0.1581	0.1592	0.1740
Number of cbg	17,782	17,782	17,782	17,782	17,782
Adj. R-squared	0.154	0.158	0.158	0.159	0.174

Note:
Estimates obtained from fixed-effects linear probability model in panel data.
Robust standard errors in parentheses.
***, **, and * denote significance at the 1%, 5% and 10% levels.

Table 7. COMPETITION

VARIABLES	(1) DSL_ENTRY	(2) DSL_ENTRY	(3) DSL_ENTRY
Variable Profits			
Firm Characteristics			
MXB	-0.0865	-0.0004	-0.1475
	(0.125)	(0.125)	(0.127)
INCOME × MXB	-0.0008***	-0.0007**	-0.0011***
	(0.000)	(0.000)	(0.000)
EDUC × MXB	0.0088	0.0011	0.0142
	(0.009)	(0.009)	(0.009)
MSO	-0.0176**	-0.0070	-0.0204**
	(0.008)	(0.008)	(0.008)
COMPLAINTS	-0.0009***	-0.0010***	-0.0008***
	(0.000)	(0.000)	(0.000)
TENURE_SHORT	-0.0681***	-0.0614***	-0.0702***
	(0.004)	(0.004)	(0.005)
TENURE_LONG	-0.0011	0.0060*	0.0077**
	(0.003)	(0.003)	(0.003)
Competition			
COMPETITORS		-0.0142***	-0.0123***
		(0.001)	(0.001)
PRICE			-0.0027***
			(0.000)
Demand			
INCOME	0.0088***	0.0116***	0.0056***
	(0.001)	(0.001)	(0.001)
EDUC	0.0320**	0.0183	-0.0117
	(0.014)	(0.013)	(0.015)
EST	-0.0030***	-0.0032***	-0.0025***
	(0.000)	(0.000)	(0.000)
AGE	-0.0016	0.0006	-0.0089
	(0.007)	(0.007)	(0.007)
HOUSING	-0.0031***	-0.0020***	-0.0016***
	(0.000)	(0.000)	(0.000)
Market Size			
POP	0.0014***	0.0010***	0.0008***
	(0.000)	(0.000)	(0.000)
Fixed Costs			
RT	0.1041***	0.0979***	0.0715***
	(0.019)	(0.019)	(0.019)
Year Fixed Effect	Yes	Yes	Yes
Constant	0.5169	0.5793	1.5699***
	(0.356)	(0.352)	(0.360)
Observations	44,727	44,727	44,727
R-squared	0.1352	0.1404	0.1485
Number of cbg	15,638	15,638	15,638
Adj. R-squared	0.135	0.140	0.148

Note:
Observations are reduced due to missing values in *COMPETITORS* or *PRICE*.
Estimates obtained from fixed-effects linear probability model in panel data.
Robust standard errors in parentheses.
***, **, and * denote significance at the 1%, 5% and 10% levels.

Appendix A. Remote Terminals (*RT*)

There is a sample data, which includes market size, variable profits, and fixed costs. The FCC Hybrid Cost Proxy Model (HCPM) data contains information on fixed costs. This section explains the merge between the FCC HCPM and the master sample data. To estimate the fixed costs of providing telecommunication networks at the census block group (CBG) level, the number of high-density remote terminals (*RT*) is chosen from the FCC HCPM workfiles. Before merging these two data sources, the duplicated CBGs in the FCC HCPM workfiles need to be dealt with. In the FCC HCPM workfiles, it is observed that a CBG contains more than one value on fixed costs. The duplicated CBGs refer to the appearance of these CBGs, which does not have a single, identical value on the fixed cost. The second issue is the number of matched CBGs between the FCC HCPM workfiles and the master sample. As the FCC HCPM workfiles contains the duplicated CBGs, a set of different values for remote terminals can be observed in a given CBG. Thus, the total number of *RT*, within the same CBG, is calculated as follows:

$$\text{No. of high density RT\_sum} = \sum_{i=1}^{n} \text{high density RT}_i \quad (1)$$

where *i=1…n* is the number of duplicated CBGs, and *RT* is the total number of remote terminals within the CBG.

The master sample data initially contains 78,225 CBGs. Among 78,225 observations, 24,936 CBGs are matched to the FCC HCPM workfiles. By merging FCC HCPM workfiles with the master sample, 32 percent of the master sample contains the information on *RT*. Running a regression of *RT* on demographic variables makes it possible to predict the number of *RT* in the unmatched CBGs. As *RT* is a count variable, poisson and negative binomial model can be applied. Because of the presence of a significant overdispersion in the poisson model, a negative binomial model is applied. Table A.1 demonstrates the coefficients obtained from the negative binomial model.

Table A. Remote Terminal in a negative binomial model

Demand controls	Coefficient
Total Population (*POP*)	-0.0002***
(in 1,000)	(0.00001)
Population Density (*DEN*)	-0.1776***
(in 1,000 people/ 1 square miles)	(0.0113)
Income (*INCOME*)	-0.0142***
(in $1,000)	(0.0001)
Age (*AGE*)	0.0338***
	(0.0013)
Population Growth Rate from 2002 to 2006	3.1539***
(*POP_GROW*)	(0.4088)
Log Likelihood	-40,630.6680
Observations	24,936
Dependent Variable: *RT*	

Source: US Census Bureau
Note:
*** denotes significance at one percent.
Robust standard errors in parenthesis.

Coefficients on demand controls in Table A can be used to estimate *RT* for all observations in the master sample. To predict *RT* in the entire sample, coefficients on each demand control are multiplied with their numerical values in the sample:

$$-0.0002*POP - 0.1776*DEN - 0.0142*INCOME + 0.0338*AGE + 3.1539*POP\_GROW \quad (2)$$

Because a negative binomial model is applied, the predicted number of *RT* in the master sample is obtained after exponentiating the multiplied numbers in the equation (2). Thus, the predicted number of *RT* is:

$$\boldsymbol{RT} = \exp\left[-0.0002*POP - 0.1776*DEN - 0.0142*INCOME + 0.0338*AGE + 3.1539*POP\_GROW\right] \quad (3).$$

Appendix B. The Random Effects Logit Model

Estimates in Table 6 and 7 are obtained from the fixed effects linear probability model. However, obtaining estimates from the fixed-effects logit was not feasible, because not many variables had annual changes in the data. Corresponding results for models (1)–(5) in Table 6 and models (1)–(3) in Table 7 are obtained by the random effects logit model. They are demonstrated in Table B.1 and Table B.2. Results obtained from the discrete choice models are consistent with those of the linear probability model. While remote terminal (RT) is the only unfortunate exception in these consistent results, no plausible explanations for this change are found. As interaction terms account for the likelihood of switching, coefficients on *MXB* become positive, and they are statistically significant at one percent in models (2)–(5). Coefficients on *INCOME*×*MXB* and *EDUC*×*MXB* are still negative, statistically significant except in model (5). When the income (or education) is high and there is mixed bundling, the probability of DSL entry is low. These consistent findings on the likelihood of switching can suggest that the probability of DSL entry is low in markets where the likelihood of switching is also low because of the high opportunity costs incurred by switching from an incumbent's mixed bundling.

Table B.1. The Random Effects Logit

VARIABLES	(1) DSL_ENTRY	(2) DSL_ENTRY	(3) DSL_ENTRY	(4) DSL_ENTRY	(5) DSL_ENTRY
Variable Profits					
Firm Characteristics					
MXB	-0.815***	11.250***	43.630***	28.160***	41.700***
	(0.125)	(0.829)	(3.590)	(3.874)	(5.123)
INCOME × MXB		-0.243***		-0.150***	-0.025
		(0.016)		(0.016)	(0.025)
EDUC × MXB			-3.266***	-1.575***	-3.027***
			(0.263)	(0.309)	(0.437)
MSO	1.223**	1.404***	1.167***	0.802*	1.013**
	(0.486)	(0.439)	(0.421)	(0.413)	(0.417)
COMPLAINTS	-0.001	0.002*	0.001	0.002*	-0.021***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
TENURE_SHORT	-4.949***	-4.962***	-4.422***	-4.537***	-2.240***
	(0.141)	(0.146)	(0.132)	(0.134)	(0.170)
TENURE_LONG	-3.768***	-3.678***	-3.299***	-3.224***	-1.031***
	(0.144)	(0.145)	(0.135)	(0.135)	(0.169)
Demand					
INCOME	-0.158***	-0.040***	-0.085***	-0.065***	-0.211***
	(0.011)	(0.011)	(0.010)	(0.011)	(0.011)
EDUC	4.656***	3.622***	2.917***	2.563***	1.674***
	(0.195)	(0.216)	(0.195)	(0.180)	(0.142)
EST	-0.047***	-0.026***	-0.030***	-0.029***	-0.021***
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
AGE	0.212***	0.194***	0.161***	0.148***	0.061**
	(0.036)	(0.031)	(0.028)	(0.027)	(0.025)
HOUSING	-0.012***	-0.013***	-0.014***	-0.014***	-0.027***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Market Size					
POP	0.018***	0.012***	0.014***	0.014***	0.018***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Fixed Costs					
RT	-2.803***	-2.511***	-2.586***	-2.465***	-2.871***
	(0.136)	(0.137)	(0.114)	(0.117)	(0.108)
Year Fixed Effect	No	No	No	No	Yes
Constant	-43.450***	-34.690***	-24.520***	-20.450***	0.856
	(2.648)	(3.080)	(2.846)	(2.579)	(1.949)
Observations	53,346	53,346	53,346	53,346	53,346
Log-Likelihood	-13,944.58	-13,894.52	-13,930.71	-13,891.94	-12,985.30

Table B.2. The Random Effects Logit

VARIABLES	(1) DSL_ENTRY	(2) DSL_ENTRY	(3) DSL_ENTRY
Variable Profits			
Firm Characteristics			
MXB	9.945*	10.420*	-0.586
	(5.962)	(5.606)	(5.550)
INCOME × MXB	-0.099***	-0.122***	-0.120***
	(0.028)	(0.022)	(0.021)
EDUC × MXB	-0.420	-0.353	0.476
	(0.503)	(0.456)	(0.451)
MSO	0.378	0.031	-1.086
	(0.752)	(0.727)	(0.748)
COMPLAINTS	-0.028***	-0.026***	-0.023***
	(0.001)	(0.002)	(0.001)
TENURE_SHORT	-1.935***	-1.936***	-2.253***
	(0.233)	(0.227)	(0.215)
TENURE_LONG	-0.236	-0.638***	-0.753***
	(0.240)	(0.240)	(0.225)
Competition			
COMPETITORS		0.570***	0.601***
		(0.042)	(0.041)
PRICE			-0.076***
			(0.007)
Demand			
INCOME	-0.218***	-0.022	-0.249***
	(0.011)	(0.015)	(0.012)
EDUC	0.300*	0.416**	0.263
	(0.165)	(0.179)	(0.172)
EST	-0.018***	-0.015***	-0.014***
	(0.001)	(0.001)	(0.002)
AGE	0.311***	0.128***	0.225***
	(0.032)	(0.035)	(0.032)
HOUSING	-0.032***	-0.020***	-0.030***
	(0.002)	(0.003)	(0.003)
Market Size			
POP	0.017***	0.011***	0.015***
	(0.001)	(0.001)	(0.001)
Fixed Costs			
RT	-4.451***	-2.166***	-3.276***
	(0.161)	(0.182)	(0.184)
Year Fixed Effect	Yes	Yes	Yes
Constant	21.130***	7.397***	20.870***
	(2.564)	(2.703)	(2.732)
Observations	44,727	44,727	44,727
Log-Likelihood	-9,735.6096	-9,977.9875	-9,830.1532

Note:
Standard errors in parentheses.
***, **, and * denote significance at the 1%, 5% and 10% levels.

Appendix C. Endogeneity

There are potential endogeneity concerns associated with the likelihood of switching variables (i.e., *INCOME×MXB* and *EDUC×MXB*) in the DSL entry equation (5). Prior studies suggest that switching costs can consist of setup (paying membership fees when changing gyms) or sunk costs (e.g., non-recoverable time, money, and effort). Consumers perceive that establishing and maintaining a relationship requires these sunk costs (Jones et al., 2002; Wise and Duwadi, 2005; Lee et al., 2006).

Basic installation fees for an incumbent's subscription TV (TV hereafter) are used as an instrument for the likelihood of switching (i.e., *INCOME×MXB* and *EDUC×MXB*). They are only for TV, and irrelevant with cable modem service. Data sources on cable systems provide basic installation fees for TV and cable modem service, separately. It is assumed that subscribers pay both basic installation fees for TV and cable modem, when they purchase mixed bundling. Therefore, basic installation fees for TV offered by an incumbent only affect demand for TV, but not the probability of DSL entry.

Basic installation costs of TV are used as an instrumental variable for the likelihood of switching. Basic installation costs of TV are one-time costs to begin the contract, and are not recoverable at the time of contract termination. Therefore, consumers who have already paid higher basic installation costs for TV can be reluctant to switch a service provider. It is possible that these costs paid in the previous period or the current period can reduce the likelihood of switching. Thus, a one-period lag in basic installation costs for TV is also included. As basic installation costs for TV do not apply to cable modem service, these sunk costs may lead consumers to be less likely to switch a service provider. However, they do not directly influence the probability of DSL entry.

The model (3) in Table 7 is estimated with this instrumental variable. Table C reports estimated results obtained from the linear probability model. In the first stage regression, F-statistics in both *EDUC×MXB* and *INCOME×MXB* regression are above ten. Both instrumental variables do not have weak instrument problems. The coefficient on *INCOME×MXB* is negative, statistically significant at one percent, while *EDUC×MXB* is not statistically significant in the second stage regression. These results can imply that the probability of DSL entry is low in markets where the likelihood of switching is also low because of the high opportunity costs incurred by switching from an incumbent's mixed bundling.

Table C. Estimates in the DSL Entry Equation with Instrument Variables

VARIABLES	(3) DSL_ENTRY
Variable Profits	
Firm Characteristics	
MXB	-0.4150
	(3.1665)
INCOME × MXB	-0.00669***
	(0.0017)
EDUC × MXB	0.0601
	(0.2319)
MSO	-0.1922***
	(0.0101)
COMPLAINTS	-0.0008***
	(0.0001)
TENURE_SHORT	-0.0286***
	(0.0083)
TENURE_LONG	-0.1017***
	(0.0202)
Competition	
COMPETITORS	0.0454***
	(0.0060)
PRICE	-0.0016*
	(0.0008)
Demand	
INCOME	-0.0131***
	(0.0020)
EDUC	0.0254**
	(0.0111)
EST	-0.00001*
	(0.0000)
AGE	0.0113***
	(0.0033)
HOUSING	-0.0015***
	(0.0001)
Market Size	
POP	0.0008***
	(0.0001)
Fixed Costs	
RT	-0.1199***
	(0.0180)
Year Fixed Effect	Yes
Constant	1.0275***
	(0.1942)
Observations	29,606
R-squared	0.1352
Number of cbg	15,638
Adj. R-squared	0.135