Market Structure and Adoption of Internet Services in Colombia

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Abstract

This paper analyzes (i) how changes in market structure affect welfare and consumer choices, and (ii) how the overall effect can be decomposed into two components: the price effect and the product variety effect. I address this analysis in the context of the Internet services market in Colombia and exploit the entry of a large telecom operator in 2008. I estimate a discrete-choice demand model and use a model of oligopolistic price-setting firms to infer marginal costs and, subsequently, to conduct various counterfactual predictions. The empirical findings indicate that market entry increased the take-up of Internet services by 6.3 percentage points and rose consumer surplus by $7.2 million (24% of the sales in 2008). The decomposition of the overall effect reveals that, on average, the price effect accounts for 62% of the total effect whereas the remaining of the overall effect can be attributed to the change of the menu of products offered by incumbent firms.

Keywords: Entry, market stucture, product variety, Internet services, digital gap.
JEL Codes: L13, L96

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1 Introduction

A large body of empirical literature in industrial organization has examined how changes in market structure, as measured by the entry of new firms, disrupt the competitive conduct in various industries. (e.g., Bresnahan & Reiss, 1991; Goolsbee & Syverson, 2008). One major insight from this literature is that (the threat of) entry has substantial effects on prices, mainly in markets with too few competitors. Recently, a strand of this literature has focused on similar questions but looking at the effect on product choice adjustment rather than prices (Boik & Takahashi, in press; Bourreau, Sun, & Verboven, 2018; Fan & Yang, in press). The common takeaway of these works is that market entry leads incumbent firms to expand their menu of product offerings. Building on these insights, it is important to account for both mechanisms (prices and menu of offerings) to understand the overall effect arising from changes in market structure. This is the main goal of this paper. More specific, I study the effect of market entry on welfare and consumer choices, and decompose the total effect into two sources: the price effect and the product variety effect[1].

In this paper, I address this analysis in the context of the Internet services market in Colombia. The Internet market is particularly relevant as it constitutes the cornerstone of the development of the so-called data economy whose value in 2018 accounted for 1.2% and 2.6% of the US and European GDP, respectively. For Europe, this sector is expected to worth about 6.3% of the GDP in 2025 (IDC, 2019). Yet, all these benefits are unevenly distributed as many people still lack access to (proper) Internet services. For example, in the US, recent estimates show that 162.8 million people living in rural areas do not have access to services at broadband speeds (Microsoft, 2018). This problem is even starker in less developed countries. As of 2017, the digital divide in Colombia (GDP per capita of $6,600) was such that the penetration rate of residential Internet services was 21.7% for low-income households and 46.8% for middle-income population (MinTIC, 2019)[2]. When analyzing the market in Colombia, it is then interesting to examine the extensive margin of demand, i.e., the choice of whether or not to subscribe to Internet services. Accordingly, in this paper, consumer choice refers particularly to the adoption of the service.

To my knowledge, this is the first work that examines the digital divide by decomposing the overall effect of market entry into the price and product variety effects. For this purpose, I use a product-level dataset covering the universe of residential Internet services that were offered in Colombia for the period 2005-2011. This sample period is particularly convenient as it captures the market conditions at a stage prior to the implementation of a series of initiatives aimed to address universal service issues (OECD, 2014). As for the change in market structure, I

[1] In this paper, price effect and pure entry effect are used interchangeably. The same applies for product variety effect and plans effect.

[2] Information on GDP per capita retrieved from the World Bank.

exploit the entry of the Internet provider Telmex in 2008. This company has been traditionally one of the largest telecom operators in Latin America and decided to enter the Colombian market by offering services via cable technologies.

The first objective of this work is to analyze how consumers make choices in the market of residential Internet services in Colombia. Specifically, the aim is to identify the parameters governing consumers' preferences and study what are the key factor influencing decisions. The second objective is to empirically quantify the impact of the entry of Telmex on welfare and adoption rates. Finally, the third objective is to gauge how much of this effect can be attributed to the pure entry of Telmex and/or to the adjustment of the menu of products by incumbent providers.

To address these objectives, I estimate a discrete-choice demand model and use a model of oligopolistic price-setting firms to infer the marginal costs of providing Internet services. Based on the notion of multiproduct Bertrand-Nash equilibrium, I use the demand estimates jointly with uncovered marginal costs to conduct several counterfactual analyses. Following Bourreau, Sun, and Verboven (2018), the counterfactuals represent alternative scenarios that differ with respect to entry decisions (Telmex and no Telmex) and the menu of products offered by incumbents.

The empirical findings show that the own-price elasticity is on average -3.6 and consumers prefer services provided via cable or DSL rather than through wireless technologies. Furthermore, the marginal utility from download speed is not monotonic for low- and middle-income consumers. For example, a consumer with an average income of $388 values positively Internet plans with speed of up to 4.4 Mbps. After this threshold, speed has a negative marginal utility. This threshold turns out to increase in the average income. Concerning the characteristics of the Internet service provider (henceforth, ISP), the representative consumer values positively the services offered by a provider that has more experience, offers services on the business segment and tends to focus only on local markets.

The main results focus on the change of adoption rate and consumer surplus in the local markets where Telmex decided to enter during the 2008-2011 period. The findings indicate that the entry of Telmex increased the adoption rate by 6.3 percentage points and rose consumer surplus by $7.2 million (24% of the sales in the year of the entry event). The decomposition of the overall effect reveals that, on average, the pure entry effect accounts for 62% of the total effect whereas the remaining of the overall effect can be attributed to the change of the menu of product offerings.

This paper mainly contributes to two strands of the literature. First, it is connected to both empirical and theoretical works that have analyzed the effect of changes in market structure on the strategic reaction of incumbents and market coverage. The theoretical literature includes papers by Johnson and Myatt (2003) and Nocke and Schutz (2018) for competitors' choices; and Yang and Ye (2008) and Foros and Kind (2003) for market coverage. As for the empirical literature, this paper builds on previous works that examine how changes in market structure may affect conduct and, in particular, the strategic responses of incumbents in terms of product offerings and prices. Several papers have investigated this in the telecommunications industry including Berry and Waldfogel (2001), Economides, Seim, and Viard (2008), Seim and Viard (2011) and Boik and Takahashi (in press). In particular, Seim and Viard (2011) evaluate the impact of the entry of new personal communication services providers in the U.S. and decompose the effect into two sources: the competitive interaction effect (direct); and the launch of new services and discontinuation of old ones (indirect). In line with this work, the current investigation attempts to measure the total effect of entry and decompose it into the pure entry and product variety effects for the Internet services market in Colombia.

The empirical analysis of the current study is perhaps closest to Bourreau, Sun, and Verboven (2018, henceforth BSV) in several ways. Firstly, BSV estimate a structural demand model, along with a two-stage supply-side model, to study how the entry of a new competitor can trigger the use of fighting brands strategy in the mobile telecommunications market in France. Similar to BSV, the current paper uses the estimates from a structural demand model, jointly with an oligopolistic model of price-setting firms, to analyze, and decompose, the effects of market entry. Secondly, the current investigation complements BSV in that it analyzes a market that is at an early stage of the diffusion process, whereas BSV consider a telecommunications market that was already saturated before entry. Thirdly, the findings of BSV ascertain the relevance of accounting for the existence of market expansion, cannibalization, and business stealing effects when studying market entry with multiproduct firms. The aim of the current investigation is to shed some light on the nature of these effects in the market of residential Internet services in a developing country.

This work is also related to a second strand of the literature that has extensively studied the market of Internet services and the digital gap. Rappoport, Kridel, and Taylor (2003) and Cardona, Schwarz, Yurtoglu, and Zulehner (2009) analyze the intra- and inter-platform substitution patterns of residential Internet services in the US and Austria, respectively. Rosston, Savage, and Waldman (2010) estimate an empirical model to study the household demand for Internet services in the US. The findings determine that the valuation for the service increases with service reliability, transmission speed, and household ICT experience. More recently, Nevo, Turner, and Williams (2016) postulate a dynamic model of decision-making subscribers to estimate the demand function for Internet services. Exploiting the dynamic variation arising from the monthly consumption under a three-part tariff, they find that consumers are heterogeneous in the willingness to pay for data transfer rate and that usage-based pricing is effective at lowering usage without affecting consumer welfare. The current investigation can be seen as complementary to these papers in that it also estimates a demand model to identify the parameters characterizing consumers' choices. However, one of the contributions of this paper to the existing literature is to analyze the Internet market for the case of a developing country.

As for the digital gap, Goolsbee (2002) studies and compares two policies focused on boosting the adoption of broadband services, namely: subsidized prices of broadband access, and investment tax credits for the expansion of the service in underserved areas. Using individual-level data on willingness-to-pay, the analysis shows that, given the presence of fixed costs, the total benefits arising from the supply-side intervention are expected to be larger than the gains obtained from the subsidy intervention. In Galperin and Ruzzier (2013), the authors attempt to identify the effect of price reductions on the adoption of fixed broadband services in Latin America and the Caribbean. The results imply that an average price reduction of $10 would raise the penetration rate by approximately 22%. Ackerberg, DeRemer, Riordan, Rosston, and Wimmer (2014) estimate a demand model for telephone services in order to understand the economic factors driving adoption choices. Using the demand estimates, they assess the effectiveness of two universal service policies aiming at increasing the penetration rate of low-income households. The results determine that the policies raised the penetration rate of poor households by 6.1 percentage points in 2000 in the US. This paper adds to the above literature in that it gauges the effect on adoption rates of changes in market structure, instead of specific interventions. Hence, the policy objective of this paper is, ultimately, to show how the digital divide in less developed countries can be overcome by increasing competition (through market entry).

The rest of the paper is structured as follows. In the next section, I review the related literature, emphasizing the contributions of this paper. In Section 2, I provide an overview of the industry, discuss the dataset, and analyze the descriptive evidence. I introduce the empirical model and outline the approach to conduct the counterfactual analyses in Section 3. The parameter estimates together with the counterfactual predictions are discussed in Section 4. In Section 5, I provide robustness checks of the demand estimates. Finally, Section 6 presents the concluding remarks.

2 Industry background and data

This section first provides an overview of the industry of Internet services in Colombia with a focus on the characteristics of the network infrastructure, the regulatory framework, and the entry of the ISP Telmex in 2008. Next, I present a brief description of the available datasets and provide the respective descriptive statistics.

2.1 Background

The infrastructure of the Internet sector in Colombia is characterized by the existence of a unique Internet Exchange Point (IXP) through which multiple telecommunication operators connect their infrastructure networks to one another using peering agreements[3]. The nature of these operators varies (e.g., Internet carri-

[3] In Colombia, the data center that enables the interconnection and exchange of domestic traffic between Internet infrastructure networks is located in Bogotá. As of 2019, the Internet exchange point

ers, content delivery networks, cloud network providers, communication providers, among others). For the provision of Internet services, the telecommunication operator may either offer connectivity services at the wholesale market, provide Internet access directly to end-users, or undertake both activities. In Colombia, there exist three main infrastructure networks owned and operated by three companies, namely: Telecom, Internexa, and TV Azteca. The former is the national telecommunications company (incumbent) that had a monopoly position over international services and was the only operator of fixed telephone lines in small towns and rural areas prior 2003[4]. As for the Internet sector, Telecom is a vertically integrated company, offering both wholesale access and retail Internet services. By contrast, Internexa focuses solely on the provision of wholesale backbone connectivity and infrastructure services. This firm has employed the network of electric energy transportation, owned by its parent company ISA, to expand a fiber-optic network in Latin America[5]. The operator TV Azteca won a tender to build the fiber-optic network in Colombia in 2011. This infrastructure has connected more than 80% of the municipalities by 2017[6]. To complete the configuration of the Internet infrastructure in Colombia, some ISPs have also rolled out their own network to provide connectivity to other companies and access to consumers. For instance, in 2003, three telecom operators (ETB, Orbitel and Internexa) jointly undertook the deployment of a fiber-optic ring to connect the Atlantic coast with the center of the country[7]. To sum up, the telecommunications fixed network in Colombia, unlike other countries, is not entirely state-owned, but it consists of multiples segments belonging to different (private) operators.

According to the review of the wholesale Internet market (CRC, 2017a, 2017b), there are 16 operators that possess their own networks (local or national) and provide access to other ISPs. Out of those operators, 11 are vertically integrated companies serving also the retail market. This creates concerns about market foreclosure. To deal with this, the Colombian regulatory framework has set the economic and technical terms and conditions for the interconnection and provision of access to essential facilities in the telecommunications sector. In this regard, the Decree 2870 of 2007 obliges operators with dominant position in the wholesale market to provide access to network infrastructure under non-discriminatory and transparent terms. Further, the ICT Law of 2009 traces the principles for access and use of essential

is managed by the IT industry association CCIT (Cámara Colombiana de Informática y Telecomunicaciones) which is a cooperative framework consisting of 20 members, out of which 7 offer residential Internet services(CRC, 2015).

[4] After the liquidation of Telecom, the company was replaced by the state-owned company Colombia Telecomunicaciones in 2003. Three years later, the central government announced the sold of the controlling interest of the company through a public offering. Accordingly, from 2006, the Spanish multinational Telefónica holds over 50% of the shares of the company (OECD, 2014).

[5] The Colombian central government holds 51% of the company and other state-owned firms hold about 17% (OECD, 2014).

[6] Retrieved from Dinero (2017). Since the deployment of the infrastructure and the provision of the services of Azteca TV began after 2011, this operator is not included in the current analysis of this paper.

[7] Retrieved from El Tiempo (2003).

facilities, indicating that the terms and conditions must be set by the regulatory authority. Accordingly, the CRC Resolution 3101 of 2011 provides a new regime of access and interconnection of wholesale networks. In particular, the regulatory authority specifies a listing of essential facilities for both access and interconnection, which can be used by any ISP by paying the respective cost-oriented charge. Even though the regulatory measures related to wholesale Internet access, such as bitstream access and local loop unbundling, are absent in Colombia, the legal framework provides instruments to implement and enforce them (OECD, 2014).

As for the quality of the Internet services, there have been two regulatory decisions aimed to mitigate information asymmetries by setting a broadband quality standard, i.e., a standard that separates high-quality (broadband) from low-quality (narrowband) services. The regulation in 2007 defined broadband services in terms of data transmission speed. More specifically, an Internet connection is considered as a broadband service if it provides download and upload speed of at least 512 kbps and 256 kbps, respectively. If those requirements are not met, the service is labeled narrowband. This quality standard was then updated in 2010 by raising the thresholds to 1024 Kbps and 512 Kbps[8].

To conclude the brief description of the market and the regulatory framework in Colombia, it is worth mentioning the milestone related to the entry of the ISP Telmex as it is exploited in Section 4.3 to gauge the impact of changes in market structure on the adoption of Internet services. Telmex is a large telecommunications company, subsidiary of the investment holding company Carso Global Telecom and acquired, in 2010, by the mobile network operator América Móvil[9]. It started providing mobile services in Colombia in 2004 after taking over AT&T Latin America. Following the failed merger with Telecom in 2006, the company decided to acquire multiple TV cable operators in 2006 and 2007[10]. The objective was to offer triple-play services (telephone, television and Internet) in Colombia. Hence, since 2008 Telmex became the largest ISP offering residential Internet services using hybrid fiber/coaxial-cable networks (CRT, 2008; Fundación Telefónica, 2011).

2.2 Data

2.2.1 Internet services

The dataset comprises all residential Internet services offered in Colombia during the 2005-2011 period[11]. This database is regularly disclosed by the ICT ministry who mandates every ISP to provide information on the menu of service offerings

[8]See the CRC Resolution 1740 of 2007 and CRC Resolution 2352 of 2010 for further information.

[9]All these companies belong to the telecommunications conglomerate owned by the businessman Carlos Slim. The consolidation of diverse companies can be seen, ultimately, as a business strategy to reinforce the competitive advantages of the companies against competitors.

[10]TV cable, Superview, Cablecentro, Cable Pacífico, and Satelcaribe.

[11]The frequency of the information is semi-annual from 2005Q4 to 2008Q4 and quarterly from 2009Q1 to 2011Q1. There are 16 periods altogether.

served in each municipality. That is, the unit of observation is the Internet service offered by an ISP to all potential consumers living in a particular municipality. Each unit of observation is associated with information on the attributes of the service (monthly fee, download speed and last-mile technology) as well as the number of households subscribed to each service. Accordingly, the Internet plan is defined as the combination of ISP, technology and download speed.

The information is complemented with two additional datasets. First, the ICT ministry in Colombia also provides information on the offers made by ISPs in the business segment. This is used to generate an indicator variable that takes the value one if the ISP provides Internet services to businesses in a determined municipality, and zero otherwise. Additionally, to complete the set of variables characterizing the business strategy of ISPs two variables are generated. The variable markets coverage denotes the number of relevant markets where the ISP is operating at a certain period of time, and the variable seniority represents the number of periods during which the ISP has served a particular market. The former variable presents variation across ISPs and over time, whereas the latter variable has additional variation across markets.

Second, the Internet database is combined with population and demographic information at the municipality level. The purpose of adding this information is two-fold. On the one hand, the total number of households (population divided by the average number of people per household) in every municipality is used as a proxy of market size, which is employed to measure the adoption rate and to estimate the demand model (Section 4.2). On the other hand, demographic information (income, education and size of the household) can be used to control for observed heterogeneity in the estimation of the parameters governing consumers' preferences. These additional sources of information are collected from the National Department of Statistics (DANE) and the household survey Gran Encuesta Integrada de Hogares (GEIH)[12].

The main limitation of adding demographic variables to the dataset is that this information is collected only for the main cities and municipalities in Colombia (24 largest cities and their respective metropolitan areas). More specific, the GEIH contains representative information for 39 out of 1024 municipalities. Such a selection of markets may generate concerns regarding sample bias. Yet these markets cover over 80% of the country's population (Vélez, 2018) and over 85% of Internet consumers before 2011. Despite this fact, in Section 5, I conduct robustness checks to discuss the validity of the results using the reduced sample.

The main sample consists of 12,171 observations (defined by the period-municipality-ISP-Internet service combination). To illustrate better the configuration of the dataset, notice that the average choice set, in any of the 39 relevant markets for a particular time period (16 in total), is such that the representative consumer can choose among 4 ISPs, each of which offers, on average, 5 unique Internet plans.

[12]This survey is the analog of the Current Population Survey conducted in the US.

Further, in line with the industry background, the largest telecom providers are (national market shares and technologies employed in parenthesis): UNE (28%; cable, xDSL and wireless), Telmex (25%; cable), ETB (19%; xDSL) and Colombia Telecomunicaciones (16%; xDSL). The national penetration rate increased by 20 percentage points during the sample period, reaching 22.4 % in the first quarter of 2011[13]. Table 1 presents the summary statistics.

Panel (A) shows that the representative Internet plan is adopted by 1,705 households which represent approximately 1% of the market share. Additionally, this average plan provides a download speed of 1.3 Mbps and is associated with a monthly fee of $37. According to the definition of quality standards in Colombia, 64 % of the plans are considered high-quality (broadband). Furthermore, nearly half of the plans are served over the phone lines (xDSL), while the remaining half is equally served using cable and wireless technologies.

	Mean	Std. Dev.	Min	Max	Obs
(A) *Plan-level:*					
Subscribers	17.05	96.40	0.01	3002.72	12171
Market share	0.01	0.02	0.00	0.30	12171
Monthly fee	37.01	23.42	10.48	140.98	12171
Speed	1.32	1.62	0.10	8.19	12171
Broadband (1/0)	0.64	0.48	0.00	1.00	12171
xDSL (1/0)	0.45	0.50	0.00	1.00	12171
Cable (1/0)	0.28	0.45	0.00	1.00	12171
Wireless (1/0)	0.27	0.44	0.00	1.00	12171
(B) *ISP-level:*					
Markets coverage	21.07	11.09	1.00	34.00	2134
Seniority	10.77	4.21	1.00	16.00	2134
Unique plans	5.70	4.12	1.00	26.00	2134
Technologies	1.19	0.45	1.00	3.00	2134
Business (1/0)	0.86	0.35	0.00	1.00	2134

Notes: Panel (A) shows the summary statistics for all plans offered in the largest 39 markets in Colombia during the 2005Q4-2011Q1 period. For Panel (B), the dataset is collapsed at the ISP-period level. Subscribers are in hundreds (100), monthly fee in US dollars and download speed in Mbps. In Panel (B), markets coverage denotes the number of markets served by the ISP. Seniority is the maximum number of periods during which the ISP has served each market. The variable technologies represents the number of last-mile technologies used by each ISP to offer the service. Business services is an indicator variable that shows whether the ISP serves the business segment.

Table 1: Summary statistics

Panel (B) provides descriptive statistics at the ISP-level. On average, a telecom provider offers services in 21 different markets. In each of those markets, the provider

[13] Note that national computations refer to the statistics calculated based on the main sample. A final remark regarding the consolidation of the database. The initial dataset was cleaned by dropping markets with a negligible number of subscribers (less than 50) or Internet plans with abnormal prices. That is, observations above the 99% price percentile which report prices greater than two-thirds of the minimum wage in 2011. Only the price criterion affects the main sample used in the current paper.

has been present for 11 periods in the sample and offers 6 unique Internet plans using the same technology. Note the variation with respect to the business strategy. Some companies target local markets, whereas others have a national scope, serving 34 out of 39 municipalities. Additionally, in certain markets, there exist providers with a unique Internet service while in some municipalities the selection of Internet services per ISP may include up to 26 different plans. Finally, it can be seen that 86 % of the ISPs offer Internet service in both the residential and business segments. In the Appendix (Table 11), I provide further statistical evidence over time.

2.2.2 Entry of Telmex

To what extent does the entry of Telmex affect prices and the menu of products offered in the markets? This subsection provides preliminary evidence to address this question. First, consider a simple reduced-form model that regresses (log of) price on the interaction term $I(Entry)_m \times I(Post)_{mt}$, a set of control variables, including characteristics of services and ISPs, and a vast array of fixed effects. In particular, the interaction term consists of two indicator variables: the dummy variable $I(Entry)_m$ that indicates whether the market m ever undergoes the entry of Telmex; and $I(Post)_{mt}$ which is equal to one after the entry event takes place in market m. The interaction term then captures the change in price for all markets that experimented the entry of Telmex in the periods after the entry[14]. Column (1) of Table 2 provides the results.

In markets that experimented entry, the estimates show that prices of Internet plans fall approximately by 6.9% after the entry event[15]. At an average monthly fee of \$37, the price of a representative Internet plan would be reduced by \$2.5. The second column shows the same exercise but using the download speed as outcome. The result indicates that the entry of Telmex is associated with an increase of 9.7% of the quality of the service. As for the third column, I repeat the same exercise but using the number of plans offered by each ISP instead of prices. The results suggest that once Telmex enters, the ISP expands its menu of product offerings by 15%. Specifically, since on average each ISP offers 5.7 unique plans, this means that entry leads on average to the offer of one additional Internet plan. The last column of Table 2 indicates the impact of the entry of Telmex on the adoption rate. In particular, the adoption rate of each market presents rises by three percentage points due to the entry of the new competitor.[16]

[14] More specifically, the reduced-form model is as follows:

$$\ln(p_{jmt}) \; = \; \gamma_1 I(Entry)_m \times I(Post)_{mt} + \gamma_2 X_{jmt} + \gamma_{3,t} + \gamma_{4,m} + \epsilon_{jmt},$$

where j is the Internet plan, m denotes the market, and t is the time period.

[15] Exactly, the prices are $exp(-0.0714) - 1 = -6.891\%$ lower.

[16] Additional comments on the reduced-form evidence. In this exercise, there is variation in treatment timing, i.e., the entry of the ISP Telmex occurs, if any, at different times for each relevant market. Overall, I observe three different groups: untreated markets where Telmex has never operated; early treated markets; and late treated markets. According to Goodman-Bacon (2018), the treatment effect

	Ln(price) (1)	Ln(speed) (2)	Ln(plans) (3)	Adopt. (4)
Entry×Post	-0.0714***	0.0926***	0.140***	0.0311***
	(0.0159)	(0.0249)	(0.0496)	(0.00635)
Observations	12,171	12,171	2,134	562
R-squared	0.608	0.665	0.607	0.936
Time FE	Yes	Yes	Yes	Yes
Mkt FE	Yes	Yes	Yes	Yes
ISP FE	Yes	Yes	Yes	-

Notes: Control variables (not reported in the table) include: download speed (and quadratic term); indicator variable for broadband connections; indicator variables for last-mile technologies; characteristics of the ISP (seniority, business services and market coverage); and municipality-specific demographic variables. For specifications (1) and (2), the unit of analysis is the Internet plan (as defined in the main text). For column (3) the observation is the period-market-ISP combination, whereas for column (4) is the period-market combination. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 2: Reduced-form regression

The reduced-form evidence indicates that the entry of Telmex affected the attributes of the Internet plans, the size of the menu of product offerings and the adoption rate at the market level. However, without further information, it is not possible to disentangle whether, for example, the price effects were driven by changes in marginal costs or changes in markups. To verify this, I use the structural model described in Section 3.[17]

The above discussion provided preliminary evidence on the effects of the entry of Telmex in all markets during the sample period. To complement this evidence, Table 3 describes statistically the characteristics of the 9 markets whose structure was affected by Telmex in 2008Q2 and makes a comparison before and after the entry. Panel (A) provides descriptive statistics of the attributes of the Internet services broken down by the type of ISP (incumbent and entrant) and technology. First, note that there is, on average, a slight decrease in the number of incumbent providers and an increase in the number of plans offered per incumbent. However, according to the test of differences between means (last column), these intertemporal changes are statistically equal to zero. Similar results are observed when the analysis is broken down by technologies, except for the number of plans offered using cable and wireless technologies. In particular, the incumbents offered, on average, two more wireless plans and two fewer cable plans in 2008Q2 relative to 2007Q4. In contrast,

of the two-way fixed effects regression is a weighted average of all possible comparisons between these groups. This takes relevance when validating the results obtained from the structural model. A series of robustness checks are presented in the Appendix.

[17]In the current version of this paper, I model the price decision of the ISPs. Adding endogenous choices regarding quality and the menu of products is work in progress.

the menu of xDSL plans did not change. A priori, this statistical analysis suggests that the product line design of Telmex (using cable technology) prompted an intra-infrastructure reaction by the incumbents and might have induced an adjustment of the menu of wireless products. With respect to the attributes of the plans in 2008, the average download speed provided by Telmex was higher than the one offered by its counterparts. On top of that, the effective price per Mbps of the new entrant is also the lowest ($47 per Mbps). This reveals the potential disruption caused by the entry of Telmex in those markets.

The panel (B) of Table 3 provides a comparison of the markets over time. The descriptive analysis shows that the adoption rate had an average increase of 62%, going from 13 percent in 2007Q4 to 21 percent in 2008Q2. Also, the concentration index indicates that each market was hypothetically served by 2 ISPs. Additionally, panel (B) provides demographic information. In 2008, the representative individual had an education level equivalent to lower secondary, an average income of $447, and lived in a household composed of 4 members[18].

	2007Q4		2008Q2		
	Mean	Std. Dev.	Mean	Std. Dev.	Difference
Panel A: ISPs					
# incumbents per market	5.86	2.25	5.38	2.04	-0.48
Plans per incumbent	5.75	2.76	6.43	5.37	0.68
Incumbents xDSL: Plans	4.58	3.02	3.81	2.54	-0.77
Incumbents xDSL: Price	43	24.71	36.03	15.59	-6.97
Incumbents xDSL: Speed	0.45	0.41	0.52	0.23	0.08
Incumbents Cable: Plans	5.87	1.41	3.87	2.33	-2***
Incumbents Cable: Price	33.71	9.32	28.56	15.78	-5.14
Incumbents Cable: Speed	0.42	0.25	0.39	0.15	-0.02
Incumbents Wireless: Plans	4.04	1.31	5.86	3.29	1.82**
Incumbents Wireless: Price	35.29	12.15	34.03	13.77	-1.26
Incumbents Wireless: Speed	0.26	0.1	0.29	0.09	0.03
Telmex Cable: Plans	-	-	4.4	2.32	-
Telmex Cable: Price	-	-	33.99	5.17	-
Telmex Cable: Speed	-	-	0.72	0.32	-
Panel B: Markets					
Adoption rate	0.13	0.07	0.21	0.09	-
HHI	0.6	0.24	0.67	0.24	-
Income	405.41	72.61	447.39	111.34	-
HH members	3.77	0.23	3.74	0.23	-
Education	4.25	0.21	4.29	0.23	-

Notes: The number of observations is 606 (Panel A), representing 18 different providers in 9 unique markets (Panel B). Prices are in US dollars and download speed in Mbps. Income (in US Dollar) and education(from 1 - 6, where 1 is no education, 4 is lower secondary education and 6 is tertiary education)are averages across individuals. Household (HH) members correspond to average across households. The source of demographic variables is the household survey Gran Encuesta Integrada de Hogares (GEIH). The last column shows the test of differences between means (across periods). *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Entry of Telmex

The following figures display the evolution of certain variables of interest by ISP.

[18]See Table 12 for the descriptive statistics of the demographic information of the full sample.

Since the market of residential Internet services can be highly fragmented at the national level, I group the ISPs in three categories, namely: large, local and other providers. In the first category, we find the largest players in the market (ETB, UNE, Telmex and Colombia Telecom). The category of local providers comprises municipality-owned companies that focus their operations in local markets (e.g., Telebucaramanga and Emcali were partially owned by the local governments of Bucaramanga and Cali and provided services mainly in those jurisdictions). Finally, the category of other providers includes Internet carriers with a negligible market share.

Figure 1 shows the evolution of the average number of plans offered per market during the sample period. It appears that there was not a unified response by the incumbents to the entry of Telmex. First, the number of plans provided by ETB and other carriers presents a slight fluctuation over time but in general remains stable. In contrast, the number of Internet plans served by UNE and local providers shows a marked increase in 2008Q2. After the entry of Telmex, the number of services remains stable at 10 plans on average. Second, the menu of product offerings of Colombia Telecomunicaciones fluctuates substantially over time. In particular, at the entry of Telmex, the provider shrinks drastically the menu of products for one year. Finally, Telmex started operations by offering, on average, 4 different plans per market. Its menu of plans remained relatively steady, showing a slight increase over time.

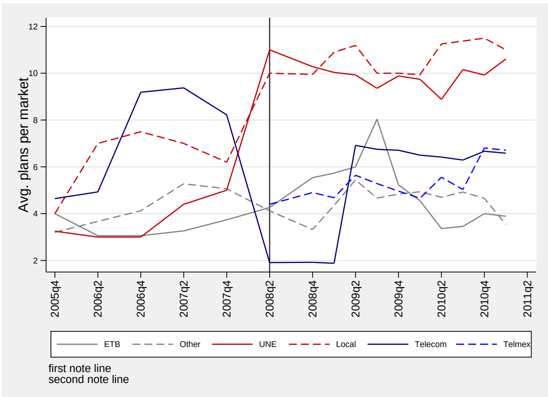

Figure 1: Entry of Telmex: Evolution of number of plans

As for the characteristics of Internet services, Figure 2 provides the evolution of the monthly fee and download speed. The left-hand side graph shows that average prices follow a decreasing trend and seem to be converging towards the end of the sample.

(a) Monthly fee (b) Download speed

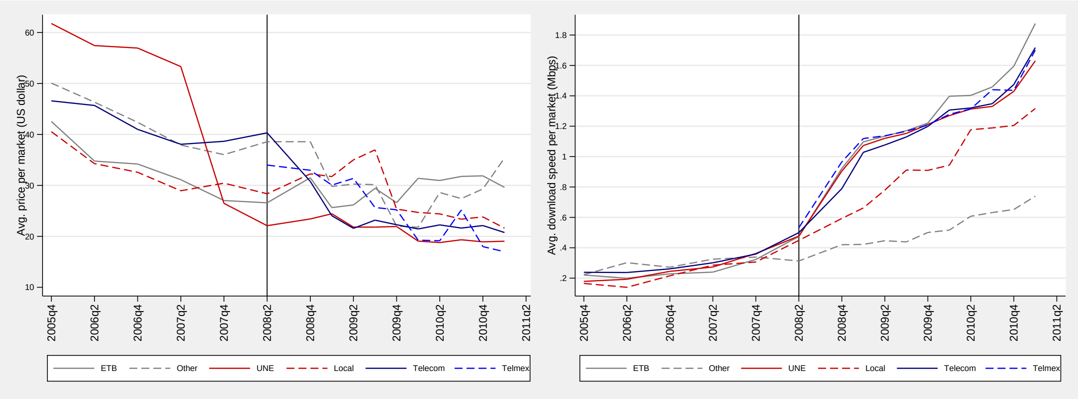

Figure 2: Entry of Telmex: Evolution of monthly fee and speed

With respect to the download speed, the right-hand side graph depicts two different (increasing) patterns before and after 2008. On the one hand, prior to 2008, the vertical differentiation was minimal in the sense that the ISPs served plans with similar average speeds. As of 2008, local and other providers started offering services with lower quality, whereas the rest of carriers continued offering similar high-quality plans. From this graphical analysis, it is difficult to determine whether the observed differentiation after 2008 can be attributed to the entry of Telmex or to the regulation of quality standards. However, it is worth noting that the upgrading of the broadband definition in 2010 seems to trigger a similar, but more moderate, reaction in the market, suggesting that the observed effect in 2008 could be the result of both entry and regulatory effects.

3 Model Set-up

This section presents the structural model used to analyze the market of residential Internet services in Colombia. Firstly, I introduce the demand model for differentiated products. Secondly, I present the supply side using a standard oligopolistic pricing setting. This model serves two purposes. On the one hand, it is used, jointly with the demand estimates, to back-out marginal costs. On the other hand, I utilize it, together with the demand parameters and uncovered marginal costs, to conduct the counterfactual predictions. In the last subsection, I focus on the counterfactual analysis in more detail.

3.1 Demand model

In this paper, I consider a discrete-choice nested logit model that contains the logit demand model as a special case. The main difference between these two models relies on how consumer tastes for Internet services are correlated. The simple logit model presents uncorrelated valuations across plans, whereas the nested model allows correlation across plans in a restricted fashion. More specific, in the nested model, the Internet services are grouped into $G + 1$ different sets ($g = 0, 1, \ldots, G.$) where group $g = 0$ denotes the outside option and the remaining groups contain a set of Internet plans $\mathcal{L}_g$. Following the network infrastructure and the regulatory framework, the market for Internet services is differentiated along two dimensions: quality level (i.e., broadband or narrowband), and type of last-mile technology. Accordingly, the set G is determined by one of these dimensions[19]. The preferences are modeled such that the indirect utility consumer i obtains from plan $j \in \mathcal{L}_g$ in market m is [20]:

$$\begin{aligned} u_{ijm} &= X_{jm}\beta_m - \alpha p_{jm} + \xi_{jm} + \zeta_{igm} + (1 - \sigma_{gm})\varepsilon_{ijm} \\ & i = 1, .., I_m \quad j = 1, ..., J_m \quad m = 1, ..., M, \end{aligned} \tag{1}$$

where X_{jm} is a k-dimensional row vector that consists of observable characteristics of the Internet plans (technology, download speed and features of the provider), p_{jm} denotes the monthly fee, ξ_{jm} is the unobserved (by the econometrician) plan characteristics, and ε_{ijm} is an idiosyncratic shock assumed to be i.i.d across plans and consumers with type-I extreme value distribution. The parameter associated with X_{jm} is $\beta_m = \beta + d_m\pi$, where the first term is a common parameter whilst the second term allows interactions between observed characteristics and aggregate demographics (d_m) of market m. The introduction of these interaction terms allows me to exploit observed heterogeneity across markets[21]. Following Berry (1994), ζ_{igm} is a group-specific variable whose distribution function depends on the within-group taste correlation parameter $\sigma \in [0, 1]$ (the nesting parameter). As σ approaches one, the Internet plans belonging to the same group are perceived as perfect substitutes. Conversely, when the parameter σ goes to zero, the preferences are uncorrelated across plans of the same group and the model becomes the simple logit[22]. Additionally, equation (1) can be rewritten as:

$$u_{ijm} = \delta_{jm} + \zeta_{igm} + (1 - \sigma)\varepsilon_{ijm}.$$

The term δ_{jm} consists of the first 4 terms of equation (1) and captures the mean utility level which is common to all consumers. Also, without loss of generality, the utility obtained from the outside option is normalized to zero. Using this, jointly with the distribution assumption, I derive the market shares and the estimation

[19] In preliminary work, I experimented with different versions of a two-level nested logit model. However, the results failed to be consistent with the random utility maximization problem (McFadden, 1978).

[20] Recall that market refers to the municipality and Internet plan is defined by the ISP, technology and transmission speed. For simplicity of exposition, I omit the index for time periods.

[21] This specification can be seen as a first approach to study consumers' choices. Ideally, I can use information on the distribution of demographics to control for unobserved heterogeneity at the consumer level. This is out of the scope of the current analysis and it is left for future research. This is further discussed in Section 6.

[22] I assume $\sigma_{gm} = \sigma$ for all groups g in every market m.

model.

Consumers are assumed to choose the alternative that gives the highest utility. Following McFadden (1978) and Berry (1994), the conditional choice probability of choosing a certain alternative can be equated to the (observed) market share. The market share of plan j is then defined as the product of the within-group share (s_{jgm}) and the group share(s_{gm}). Specifically, the market share of plan j in group g is:

$$s_{jgm} = \frac{\exp(\delta_{jm}/(1-\sigma))}{D_{gm}},$$

where $D_{gm} := \sum_{j \in \mathcal{L}_{gm}} \exp(\delta_{jm}/(1-\sigma))$. Similarly, the probability of subscribing to a plan belonging to group g in market m is:

$$s_{gm} = \frac{D_{gm}^{(1-\sigma)}}{\sum_g D_{gm}^{(1-\sigma)}}$$

As a result, the market share expressions for plan j and the outside good are[23]:

$$s_{jm} = \frac{\exp(\delta_{jm}/(1-\sigma))}{D_{gm}^{\sigma}\left(\sum_g D_{gm}^{(1-\sigma)}\right)} \tag{2}$$

$$s_{0m} = \frac{1}{\left(\sum_g D_{gm}^{(1-\sigma)}\right)} \tag{3}$$

Berry (1994) shows how this market share system can be inverted to obtain an analytic expression for the mean utility δ_{jm}. The resulting equation relates differences in log market shares to (observed and unobserved) characteristics of the Internet plan. The estimation equation of the nested logit model is then as follows:

$$\ln(s_{jm}) - \ln(s_{0m}) = X_{jm}\beta_m - \alpha p_{jm} + \sigma \ln(s_{jgm}) + \xi_{jm}. \tag{4}$$

The details of the specification, estimation and potential identification issues are discussed in Section 4.1. Finally, the observed market shares are computed using the potential size of the markets. This is key to determine the market share for the outside good and the adoption rate of residential Internet services. Accordingly, the market share s_{jm} is defined as the number of subscribers of plan j divided by the size S_m of the respective market.

3.2 Oligopoly pricing

Internet service providers are multi-product companies offering a wide variety of Internet plans. Hence, I assume that market competition is characterized by a multi-product Bertrand-Nash equilibrium. That is, each ISP sets monthly fees to maximize total profits over all its products, taking as given the prices set by other

[23]Note that $\delta_{0m} = 0$ and, hence, $D_{0m} = 1$

companies.

Formally, each ISP f owns a set $\mathcal{F}_{fm}$ of J_m different Internet plans offered in market m[24]. Omitting the time index, ISP f's total variable profits π_{fm}^V in market m is given by

$$\pi_{fm}^V = \sum_{j \in \mathcal{F}_{fm}} (p_{jm} - c_{jm}) s_{jm}(\mathbf{p}) S_m, \tag{5}$$

where c_{jm} is the constant marginal cost of plan j, S_m denotes the total number of potential consumers in market m, and s_{jm} is the share of plan j in market m expressed as a function of the J dimensional vector $\mathbf{p}$. Assuming the existence of a pure-strategy Nash equilibrium, the system of first-order conditions is defined as:

$$s_{jm}(\mathbf{p}) + (p_{jm} - c_{jm}) \frac{\partial s_{jm}(\mathbf{p})}{\partial p_{jm}} + \sum_{\substack{k \in \mathcal{F}_{fm} \\ k \neq j}} (p_{km} - c_{km}) \frac{\partial s_{km}(\mathbf{p})}{\partial p_{jm}} = 0, \qquad j = 1, \ldots, J_m.$$

This set of conditions involves three terms, which reflect the tradeoff made by a profit-maximizing multi-product firm. First, a small unit price increase for product j raises the price-cost margin. This gain is proportional to the market share at the current price. Second, a unit price increase also reduces the demand for product j and this implies a profit loss which is proportional to the current price-cost margin. Third, the price increase also affects positively the demand for other products served by the same firm. More specific, a unit price increase raises the market share of other products k and this entails gains that are proportional to the margins of these products. At equilibrium, all effects offset one another. Furthermore, I can express this system of first-order conditions for a particular market as follows:

$$s(\mathbf{p}) + (\theta^{\mathcal{F}} \odot \Delta(\mathbf{p}))(\mathbf{p} - \mathbf{c}) = 0. \tag{6}$$

The term $s(\mathbf{p})$ is a $J \times 1$ market share vector and $\theta^{\mathcal{F}}$ is a $J \times J$ ownership matrix, where the element $\theta_{jk}^{\mathcal{F}}$ is equal to 1 if Internet plans j and k are served by the same ISP, and 0 otherwise. The matrix $\Delta(\mathbf{p}) = \frac{\partial s_(\mathbf{p})}{\partial \mathbf{p}'}$ is a $J \times J$ derivative matrix which includes the demand estimate $\hat{\alpha}$. Following the literature on merger simulation (e.g., Björnerstedt & Verboven, 2014), I use equation (6) to back out product-specific marginal costs $\hat{\mathbf{c}}$ and to conduct the counterfactual analyses. These are explained in more detail in the next subsection.

3.3 Counterfactuals

To perform the counterfactual analyses, the system of first-order conditions (6) can be inverted to solve for the equilibrium price:

$$\mathbf{p} = \mathbf{c} - (\theta^{\mathcal{F}} \odot \Delta(\mathbf{p}))^{-1} s(\mathbf{p}). \tag{7}$$

[24] In the dataset, I observe that the choice set varies across markets and the subset of products offered by the provider f is also market-specific.

This equation can be used to compute the equilibrium under different scenarios. More specifically, under the assumption that there are no changes related to marginal costs, the counterfactuals involve changes in the product ownership matrix $\theta^{\mathcal{F}}$. The different ownership matrices not only aim to represent the change in market structure due to the entry of the new competitor Telmex but also aim to decompose the change into two components, namely: the pure entry effect and the product variety effect.

More formally, I use four different ownership matrices, each representing a counterfactual scenario. Take the entry of Telmex in 2008Q2 as an example. The scenario I ($\theta^{\mathcal{F},\mathrm{I}}$) is the *status quo* which represents the market after the entry of Telmex in 2008Q2. That is, the market structure is such that Telmex competes with the incumbent providers and they offer a particular menu of product offerings (new plans). The opposite counterfactual is the scenario IV ($\theta^{\mathcal{F},\mathrm{IV}}$). This scenario reflects the setting in which Telmex is not in the market and the incumbent firms offer the menu of product offerings that they would have offered, had Telmex not entered the market (old plans). To this end, I use the menu of Internet plans that were served in the last period before the entry of Telmex (2007Q4). The scenarios II and III are intermediate counterfactuals in that they represent step-wise changes. The former describes the setting with Telmex and old plans ($\theta^{\mathcal{F},\mathrm{II}}$), whereas the latter represents the structure without Telmex and new plans ($\theta^{\mathcal{F},\mathrm{III}}$)[25]. I conduct the above-explained analysis for all entry events observed during the sample period.

To simulate the new price equilibrium, I use fixed point iteration on equation (7) with a dampening factor (Björnerstedt & Verboven, 2014). In each of the above-mentioned counterfactuals, based on the new prices, I compute the adoption rate at the market level (total number of subscribers divided by the market size), producer surplus (total variable profits), and consumer surplus. The latter is determined (up to a constant) by the so-called log-sum term divided by the marginal utility of income (Train, 2009)[26].

Using the market outcomes for each counterfactual, I finally define the effects of changes in market structure. The total effect is measured by the change between scenario I and IV. This can be decomposed as the sum of the pure entry effect and the product variety effect. On the one hand, the pure entry effect gauges the effect of the entry of Telmex, holding the menu of products fixed. That is, it is the difference between scenario II and IV. On the other hand, the product variety effect

[25] In practice, I implement these counterfactual scenarios as follows. Starting from the status quo, for scenario III, I remove all products (rows) offered by Telmex in 2008Q2 and define the new matrix $\theta^{\mathcal{F},\mathrm{III}}$. Similarly, for scenario IV, I remove Telmex and the menu of products offered in 2008Q2 by the incumbents. Then, I insert all Internet plans that were offered by the incumbents in 2007Q4. The resulting ownership matrix is defined as $\theta^{\mathcal{F},\mathrm{IV}}$. The scenario II follows the same logic.

[26] Here I provide additional details on the implementation of the counterfactuals. I use a dampening factor of 0.3 and a tolerance level of $1e^{-6}$ for the fixed point iteration. Further, the ownership matrix has to be complemented by two other matrices. The market matrix to indicate which products belong to the same market and the group matrix which serves the same purpose but with respect to the segments. The latter matrix is particularly important to compute correctly the own- and cross-price elasticities in the nested logit model. The elasticities are directly derived using the expressions for the market shares.

measures the effect of changes in the menu of products, holding the entry status of Telmex fixed. This is given by the difference between scenario I and II. Note that these effects can be alternatively defined using scenario III. Table 16 in the Appendix provides a diagram with all scenarios.

4 Results

This section is divided into three parts. First, I discuss the specification and identification issues of the demand model. Next, in the second subsection, I present and interpret the demand estimates together with the implied elasticities and marginal costs. The final subsection then provides the results of the counterfactual predictions.

4.1 Demand specification and estimation

Specification. The empirical analysis is based on the demand model (equation 4.1). The groups of the nested logit model are defined according to the technology used to provide the service (cable, xDSL or wireless). The vector X_{jm} consists of plan-specific characteristics: download speed and indicator variables denoting the last-mile technology[27]. It also includes a set of features characterizing the business strategy of each ISP: business services, markets coverage and seniority. Further, it contains the vector of socio-demographic variables d_m (average income, education and household size) and fixed effects for ISPs, markets and time periods. These fixed effects variables capture unobserved time-invariant ISP- and market-level heterogeneity, and time-specific aggregate shocks. Finally, to account for observed consumer heterogeneity, I interact the average income with all plan-specific characteristics[28].

Identification. To estimate the parameters governing consumers' preferences, I need to account for identification issues of the demand model (4.1). The main econometric challenge is to identify the parameters of the model as there are unobserved characteristics (by the econometrician) that may be correlated with observed attributes of the Internet services. Particularly, this concern is related to the price coefficient and the nesting parameter.

As for the price coefficient, the endogeneity issue arises since pricing decisions depend on unobserved quality characteristics of the Internet services (included in the structural error term ξ_{jm}). If ISPs set optimal prices accounting for all product characteristics, then p_{jm} may be correlated with ξ_{jm}. For instance, the structural

[27]The technology has three mutually exclusive and exhaustive categories. In the econometric model, wireless is the reference group. Additionally, to capture a non-linear preference for the transmission speed, I include a quadratic term for download speed

[28]This is the most preferred specification. In principle, I could have interacted all demographic variables with the vector X_{jm}, and even with the endogenous variables. However, this task proved to be demanding in terms of variation.

error term can be associated with the quality features of the Internet services that affect positively both price and consumers' utility. If the demand model were to be estimated using OLS, one could expect then the price coefficient to be (in absolute value) underestimated. With respect to the nesting variable ($\ln(s_{jgm})$), the endogeneity bias is due to the construction of the model. Any unobserved characteristic that raises s_{jm} would increase also s_{jgm}. Hence, the OLS estimate of the nesting parameter would be upward biased (closer to one).

To overcome this, I employ instrumental variables that are in the spirit of Berry, Levinsohn, and Pakes (1995, henceforth BLP). That is, for the Internet plan j in market m, I employ the sum of observed product characteristics of the other plans offered by the same provider and the sum of characteristics of plans served by competitors in the same market. Following Verboven (1996), I use the sum of characteristics by groups (i.e., technologies) as additional instruments for the nested logit model[29].

The identification of the demand parameters requires the set of instrumental variables to satisfy two conditions. First, the instruments must be excluded from the demand equation (exogenous). On this point, the identifying assumption is that the location of the Internet plans in the characteristics space is exogenous. Second, the set of instruments must be relevant (i.e., correlated with the endogenous variables). This is indeed the case under the assumption that ISPs optimally choose characteristics before setting prices[30]. In the empirical analysis, I test the validity of the second assumption using the weak identification test.

Estimation. I estimate the two-step feasible generalized method of moments (GMM) using the above-discussed set of instruments to define the orthogonality conditions. The presence of heteroskedastic errors makes the GMM estimator more efficient than the 2SLS estimator (Baum, Schaffer, & Stillman, 2003)[31]. Additionally, I use robust standard errors that allow serial correlation and heteroskedasticity. These standard errors are clustered on Internet providers as it is likely to find an ISP effect that induces correlation across different Internet plans offered by the same provider.

4.2 Demand estimates

Table 4 reports the demand estimates for both the simple logit and the nested logit model. For each model, I estimate the OLS and IV estimators. By doing so, I show the existence and direction of the endogeneity bias. For both the price and nesting coefficients, note that the OLS estimator is upward biased. The OLS price coefficients have the expected sign but are small in magnitude, whereas the OLS nesting

[29]In particular, the set of instruments includes the variables: download speed, technology, seniority, market coverage, and the constant term. The latter variable denotes the count of the number of other products.

[30]These assumptions are valid if we consider the characteristics as predetermined variables at the pricing stage and with a slow adjustment over time (Verboven, 2002).

[31]I test for the presence of heteroskedastic errors using the Breusch-Pagan and Pagan-Hall tests.

parameter is close to its upper bound. This bias is corrected by using instrumental variables which, I show, are robust to the weak instrument and overidentification tests[32]. More specific, in both models (Logit and Nested IV), the price coefficient becomes larger in magnitude (in absolute value) and, in the nested IV model, the nesting parameter remains significant but becomes smaller.

The nested logit model using instrumental variables is the preferred model (last column of Table 4). The reason is that it solves the endogeneity issue (as already discussed) and rejects the simple logit model (i.e., $\sigma \neq 0$). As for the estimated parameters, the nesting parameter σ is statistically significant and lies in the unit interval, satisfying the conditions imposed by the utility maximization (McFadden, 1978). This means that consumers' valuations are correlated within groups, i.e., Internet plans compete closely with plans of the same technology segment. For instance, an increase in the price of Internet plans served through cable technologies has a relatively higher effect on the demand for plans using the same technology than for plans served using xDSL or wireless.

In general, the demand estimates have expected signs and are precisely estimated (except for the education parameter). Consider first the demand estimates without accounting for the interactions[33]. The average consumer places positive valuation for services offered using cable and xDSL technologies relative to the wireless technologies. The marginal utility from download speed is not monotonic. Consumers value positively plans with speed of at most 3 Mbps. After this cutoff, the valuation decreases in speed. This result could be partly explained by the relationship between speed and fees. With respect to the attributes of the ISPs, note that the representative consumer values positively the Internet plans offered by a provider that has been more years in the market (i.e., with more experience), offers services on the business segment and tends to focus on local markets.

[32] More specifically, the bottom rows of Table 4 provide the Kleibergen-Paap Wald F statistic and the p-value of the Hansen J test. The former is employed to test the relevance of the instrumental variables. According to the critical values proposed by Stock and Yogo (2005), I reject the null hypothesis that the instruments are not relevant (weak). As for the Hansen J test, I check the validity of the overidentifying restrictions. This can be done since the GMM model is overidentified. According to the p-value, I fail to reject the joint null hypothesis that the instruments are valid.

[33] Here I abuse the results for ease of the analysis. Yet, without interactions is equivalent to making the analysis for an extremely low-income consumer.

	Logit		Nested	
	OLS	IV	OLS	IV
Price	-0.0512***	-0.108***	-0.00572***	-0.0541***
	(0.00474)	(0.0136)	(0.00156)	(0.00247)
$\ln(s_{jgt})$			0.906***	0.478***
			(0.0160)	(0.0215)
Cable (0/1)	1.971***	1.613***	1.489**	1.726***
	(0.334)	(0.237)	(0.650)	(0.125)
xDSL (0/1)	0.853	1.154***	1.623***	1.411***
	(1.121)	(0.249)	(0.354)	(0.0827)
Speed	0.363	1.297***	0.142	0.554***
	(0.481)	(0.269)	(0.0938)	(0.0634)
Speed^2	-0.115	-0.183***	-0.0287*	-0.0895***
	(0.0721)	(0.0318)	(0.0150)	(0.00858)
Income×Cable	0.0618	0.0657	0.373**	0.221***
	(0.155)	(0.0489)	(0.138)	(0.0321)
Income×xDSL	0.206	0.0394	0.404***	0.266***
	(0.178)	(0.0811)	(0.104)	(0.0248)
Income×Speed	0.0407	0.0135	-0.00580	0.0169*
	(0.121)	(0.0478)	(0.0218)	(0.00862)
Income×Speed^2	0.00593	0.00916*	0.00391	0.00531***
	(0.0134)	(0.00545)	(0.00343)	(0.000944)
Income	-0.139	-0.0587	-0.230***	-0.174***
	(0.0934)	(0.0503)	(0.0535)	(0.0167)
Education	-0.0435	0.0748	0.0118	0.0311
	(0.153)	(0.136)	(0.0998)	(0.0487)
HH members	0.0753	0.239***	0.0783	0.129***
	(0.120)	(0.0781)	(0.0864)	(0.0229)
Firm seniority	0.161	0.230***	0.0808	0.134***
	(0.115)	(0.0209)	(0.0644)	(0.00696)
Business (0/1)	0.0198	0.0130***	0.00373	0.0109***
	(0.0153)	(0.00349)	(0.00557)	(0.00103)
Markets coverage	-0.000510	-0.0123***	0.00223	-0.00362***
	(0.00390)	(0.00203)	(0.00223)	(0.000576)
Observations	12,171	12,171	12,171	12,171
Markets	39	39	39	39
ISP	34	34	34	34
FE	Yes	Yes	Yes	Yes
Weak IV		25.71		51.35
Hansen p-val		0.522		0.298

Notes: Markets and ISP refer to the total number of unique markets and providers in the dataset. The time period is 2005Q4-2011Q1. See the data description for detailed information on the structure of the database. The market segmentation related to s_{jtg} is given by last-mile technologies (and outside option), namely: xDSL, cable, and wireless. Robust standard errors in parentheses are clustered on Internet service providers. Each specification includes time-, market- and ISP-fixed effects. The weak IV test corresponds to the Kleibergen-Paap test. Prices are in US dollars, speed is in Mbps and income (in US dollars) is scaled as income/100.*** p<0.01, ** p<0.05, * p<0.1.

Table 4: Demand estimates

Now consider the socio-demographic variables and the interaction terms. Household size has positive marginal utility, whereas education is statistically insignificant. An interesting pattern emerges when income is analyzed together with the interactions. For wireless services, the higher the income the lower is the valuation for residential Internet services relative to the outside option, which includes, among others, mobile Internet services. Conditional to the attributes of the service, this means that if there is no other technology available, well-off consumers are more likely to adopt mobile services instead of subscribing to fixed Internet services. In contrast, for cable and xDSL plans, high-income consumers derive higher utility than low-income consumers. With respect to the data transmission speed, the pattern of the marginal utility of speed is the same as explained above, provided the consumer earns less than \$1,685 per month. The only difference is that the speed cutoff increases in the average income. For instance, a consumer with an average income of \$388 (see Table 12) values positively Internet plans with a download speed of up to 4.4 Mbps. After this cutoff, download speed has negative marginal utility. In contrast, consumers with an average income of at least \$1,686 derive more utility from speed, regardless of the speed level[34].

Table 5 shows the implied average own-price elasticity, marginal cost and markup. For the nested logit model, the own-price elasticity is -3.6. This means that the demand for a representative Internet plan increases by 3.6% due to a 1% reduction in price. The corresponding marginal cost is \$29.2 which accounts approximately for 78.9% of the average monthly fee (See Table 1) and the mean percentage markup is 30%.

	Obs.	Mean	Std. Dev.	Min	Max
Logit					
Elasticity	12171	-4.0	2.5	-15.3	-1.1
Marginal cost	12171	28.2	23.4	1.4	132.0
Markup	12171	0.3	0.2	0.1	0.9
Nested					
Elasticity	12171	-3.6	2.4	-14.4	-0.6
Marginal cost	12171	29.2	23.7	-7.8	134.4
Markup	12171	0.3	0.2	0.0	1.7

Table 5: Elasticity, marginal cost and markup

There is one caveat related to the implied substitution patterns. Using the nested logit model, some of the own-price elasticities are (in absolute value) less than one which implies negative marginal costs (opportunity costs) and markups above one. As shown by the top panel of Table 5, this is not the case for the simple logit model. Despite the presence of unrealistic own-price elasticities and marginal costs, I choose the nested logit model to conduct the counterfactual predictions as it entails more flexible substitution patterns than the simple logit model.

Finally, Table 6 reports the evolution of these variables over time. In short, I can summarize the pattern that emerges from this analysis as follows: consumers have become less price-sensitive, the cost of providing the service has fallen and market power has risen over time. Yet, the magnitude of these results is driven by the functional form of the demand model and thereby it is exacerbated by the steady

[34]This analysis is based on the following expression for the marginal utility of speed:

$$\frac{\partial u_{ijt}}{\partial \text{speed}_{jt}} = (0.554) + (0.0169) \times \text{Income}_t + 2 \times (-0.0895 + 0.00531 \times \text{Income}_t) \times \text{speed}_{jt}$$

Recall that speed is in Mbps and income (in US dollars) is scaled as income/100.

decrease in prices. I discuss how to overcome these tackles (negative marginal costs and functional-form dependence) in future research in Section 6.

	Own-price elasticity	Marginal cost	Markup
2005	-7.043	64.549	0.151
	(3.86)	(36.05)	(0.09)
2006	-6.178	54.711	0.173
	(3.36)	(31.84)	(0.11)
2007	-5.38	45.997	0.209
	(3.25)	(31.31)	(0.13)
2008	-3.769	30.614	0.256
	(2.21)	(21.02)	(0.13)
2009	-3.26	25.335	0.291
	(1.88)	(18.2)	(0.15)
2010	-2.991	22.775	0.326
	(1.89)	(18.48)	(0.19)
2011	-2.684	19.99	0.326
	(1.44)	(13.9)	(0.18)

Notes: Each column shows the average and standard deviations (in parentheses) of each variable. The computations are obtained using the nested logit demand estimates jointly with the equilibrium conditions of price-setting multiproduct firms.

Table 6: Elasticity, marginal cost and markup

4.3 Counterfactual analysis

This paper aims to address the question of how the entry of Telmex affected welfare and the adoption rate in the market of residential Internet services in Colombia. Furthermore, the specific objective is to compute the total effect and decompose it into two components: the pure entry and the product variety effect. Based on the demand estimates and uncovered marginal costs, I use equation (7) to provide an answer to this question. More specific, I compute the price equilibrium (adoption rates and welfare measures) using different ownership matrices for each of the counterfactual scenarios. Recall that these scenarios are defined as follows: scenario I is the status quo (Telmex and new plans); scenario II (Telmex and old plans); scenario III (No Telmex and new plans); and scenario IV (No Telmex and old plans)[35].

When computing the counterfactual predictions, I implicitly make several assumptions (Nevo, 2000). First, the marginal costs stay the same before and after either the entry of Telmex or the adjustment of the menu of product offerings. Second, the demand estimates also remain constant which implies that the gross valuation of each Internet plan (mean utility without price) and the value of the outside option also do not change. Third, the entry (or exit) of Telmex and the adjustment of the choice set do not trigger the entry (or exit) of any competitor.

[35]See Section 3.3 for further details

Table 7 presents the results for the markets that experimented the entry of Telmex during the sample period. In the scenario I (status quo), the Internet adoption rate is 20.6% and the consumer (up to a constant) and producer surpluses are \$12.7 and \$23 million, respectively. In contrast, before the entry of Telmex and the adjustment of the menu of products (scenario IV), all three measures present a substantial reduction. Specifically, the adoption rate decreases by 6.3 percentage points, whereas both surpluses fall by approximately \$6 million. These results constitute the total effect of the entry of Telmex. To put these findings into perspective, the increased penetration rate amounts to having about 251 thousand more subscribers (households), whereas the total consumer surplus gains amount to 24% of the total \$30 million sales in these markets in 2008Q2. The decomposition of the effect reveals that the pure entry effect accounts for 64% of the total effect on the adoption rate and for 58% of the total effect on consumer surplus. In short, as far as the adoption rate and consumer surplus are concerned, I find that the entry of Telmex boosted the take-up of residential Internet services and raised consumer surplus. On average, 62% of the effect is due to the pure entry of Telmex and 38% is due to the change of the menu of product offerings.[36]

	Telmex		No Telmex		Total Effect (I-IV)	Decomposition (%)	
	New plans (I)	Old plans (II)	New plans (III)	Old plans (IV)		Plans effect	Telmex effect
Adoption (%)	20.6	18.37	16.81	14.28	6.33	35.22	64.78
Consumer surplus	12.73	9.74	7.97	5.53	7.21	41.56	58.44
Producer surplus	22.99	20.71	18.99	16.17	6.82	33.43	66.57

Notes: The first four columns show the outcomes of 4 different scenarios that differ with respect to the entry of the provider Telmex and the offering of new or old plans. The scenario (I) is the status quo in 2008Q2. As for scenarios (II) and (IV), the set of old Internet plans is formed using the offers of the last quarter of 2007. Total effect (Column 5) is the difference between scenario (I) and (IV). The last two columns decompose (in percentage) the total effect into the plans effect (I-II) and the pure entry effect (II-IV). The number of markets analyzed is 30. Thus, the adoption rate represents the total number of subscribers divided by the total market size in those 30 markets. Consumer surplus (up to a constant) is given by the log-sum term divided by the marginal utility of income (Train, 2009). Producer surplus is the sum of total variable profits over Internet providers. Surplus is expressed in million of dollars and price in dollars.

Table 7: Counterfactual analysis and effect decomposition

Table 8 reports the decomposition of the total effect on profits (in thousands), prices and (average) market shares broken down by ISP. Consider first the product variety effect. We can see that the incumbents would have adjusted their menu of products (except for Coldecon), had Telmex been hypothetically in the market before the actual entry. This suggests that the entry of Telmex prompted the change in the product line design. Now consider the Telmex effect. It is interesting to note that the largest price reduction is associated with those ISP that offer Internet services only through cable technologies (Cable Vision and Supercable).

[36] I interpret the results related to the producer surplus with caution since about 5% of the observations present negative marginal costs, affecting mostly the calculations of the total variable profits. This is work in progress.

Furthermore, the change in profits confirms the intuition provided above. The entry of Telmex spurred competition and reduced the profits of incumbent Internet providers. Finally, Table 17 of the appendix displays the results broken down by year. It is only worth indicating that the entry of Telmex seems to have affected the market only during the first year of operation of the provider.

	Plans effect (I-II)			Telmex effect (II-IV)		
	$\Delta\pi$	Δprice	Δshare	$\Delta\pi$	Δprice	Δshare
Axesat	0.02	-7.23	0	-0.01	0	0
Cable Visión	12.05	34.74	0.16	-37.5	-8.47	-0.2
Coldecon	-11.71	-1.68	-0.04	-0.98	0	0
Colombia Telecom	372.11	-18.44	0.59	-38.19	-0.02	-0.08
ETB	1127.17	-2.8	0.31	-378.97	-0.02	-0.13
Emcali	229.22	-2.35	2.08	-10	-0.01	-0.09
Supercable	37.72	-16.02	0.16	-605.44	-9.05	-1.22
Telepereira	61.42	6.51	1.98	-72.13	-2.62	0.24
Telmex	-292.47	-1.29	-0.21			
UNE EPM	360.01	-12.28	0.93	-141.86	-0.37	0.07
Unitel	2.41	15.56	0.04	-0.19	0	0

Notes: This table shows the change in variable profits ($\Delta\pi$), average price and average market share (per market) between different counterfactual scenarios. Plans effect represents the change between scenario I and II, whereas Telmex effect is the difference between scenario II and IV. All variables are averages across markets for each ISP. Δprice is in US Dollars, and profits are expressed in thousands of dollars.

Table 8: Counterfactual analysis: Plans and Telmex effect by ISPs

To sum up, the empirical results suggest that the change of market structure, as measured by the entry of Telmex, had positive effects on consumer surplus and spurred the adoption of residential Internet services. The implication of this evidence is that policymakers should promote the entry of new competitors by providing either direct incentives or by mitigating entry barriers. This is even more relevant for less developed countries where the diffusion and adoption of Internet services are still of first-order importance. In the case of Colombia, this implication is in line with the recommendations made by the OECD (2014) regarding wholesale obligations (local loop unbundling and wholesale broadband access) and the provision of services in rural places where the network infrastructure cannot be replicated.

Furthermore, the decomposition of the total effect shows that nearly 38% of the positive impact on the adoption rate can be attributed to the adjustment of the menu of product offerings. This finding suggests alternative policies that can be implemented to speed up the take-up of Internet services at a relatively low cost. For instance, the regulatory authority may request the ISPs to regularly update the menu of products, and it could set the respective information disclosure regime to keep consumers well informed about these changes. Alternatively, the regulatory authority could require each carrier to offer a homogeneous menu of plans across markets. This policy would automatically adjust the menu of products in various markets and, following the empirical evidence, increase the adoption rate. The analysis of the policy implications is an interesting path of future research.

5 Robustness Checks

In this section, I conduct two robustness checks of the demand estimates. First, Table 9 presents the OLS and IV estimators for different specifications of the nested logit model. These specifications differ along two dimensions from the main results of this paper. On the one hand, by adding different regressors step-wise, I analyze how the estimates behave and how much they change relative to the ones presented in the main text of this paper. We can see, in Table 9, that the price coefficient as well as the nesting parameter have the expected sign and are virtually identical across specifications for each of the estimators (OLS and IV). On the other hand, in this set of specifications, I do not control for observed consumer heterogeneity. To some extent, this shows how the inclusion of the demographic variables (and the interaction terms) affects also the main estimates. Consider specifications (4) and (8). The price and nesting coefficients are precisely estimated and rather similar to the main results of this paper (last two columns of Table 4). This is also the case for the ISP's attributes[37].

Second, Table 10 shows the sensitivity of the results under distinct samples. The columns (1)-(4) use the raw dataset, where we can see that the total number of markets amounts to 595, covering all subscribers during the period 2005Q4-2011Q1. The columns (5)-(8) show the estimates employing the clean database, i.e., after dropping abnormal observations and plans with negligible market shares (see Section 2.2 for further details). Note that even though the consolidated sample uses about half of the markets, it still covers 99% of the total subscribers. The final specifications, columns (9)-(12), correspond to the main sample used in this paper. This sample uses information of 6% of the markets but captures the behavior of 87% of the consumers in Colombia. For comparison purposes, consider only specifications (8) and (12). In both specifications, the price coefficient and the nesting parameter are sharply estimated and have the expected sign. Moreover, the coefficients prove to be statistically equal across the samples[38]. Hence, the main estimates are not sensitive to analyzing only the main cities in Colombia. This is the case for the counterfactuals as well because these estimates are the basis for these analyses.

[37]For the remaining variables, there is not a direct comparison due to the interactions.

[38]In practice, I combine the samples (consolidated and main cities) and run the model using an indicator variable for the consolidated sample and including interaction terms (with all regressors and instruments). The estimates associated with the interactions allow me to test the statistical equivalence across samples.

	OLS				IV			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Price	-0.00437***	-0.00561***	-0.00532***	-0.00582***	-0.0678***	-0.0588***	-0.0595***	-0.0541***
	(0.00106)	(0.00113)	(0.00142)	(0.00149)	(0.00154)	(0.00254)	(0.00197)	(0.00247)
$\ln(s_{jgt})$	0.906***	0.902***	0.908***	0.904***	0.406***	0.461***	0.468***	0.477***
	(0.0169)	(0.0159)	(0.0169)	(0.0167)	(0.0134)	(0.0174)	(0.0183)	(0.0206)
Cable (0/1)	2.990***	2.952***	2.978***	2.948***	2.870***	2.559***	2.736***	2.596***
	(0.165)	(0.161)	(0.160)	(0.158)	(0.0206)	(0.0251)	(0.0148)	(0.0238)
Xdsl (0/1)	3.264***	3.219***	3.246***	3.218***	2.731***	2.435***	2.573***	2.470***
	(0.371)	(0.376)	(0.359)	(0.369)	(0.0317)	(0.0237)	(0.0216)	(0.0252)
Broadband (0/1)		0.132***				1.010***		
		(0.0463)				(0.0505)		
Speed			0.0266	0.116**			0.210***	0.617***
			(0.0328)	(0.0473)			(0.0166)	(0.0389)
Speed^2				-0.0131***				-0.0675***
				(0.00384)				(0.00546)
Firm seniority	0.0752	0.0789	0.0759	0.0787	0.122***	0.147***	0.121***	0.132***
	(0.0649)	(0.0641)	(0.0643)	(0.0643)	(0.00686)	(0.0102)	(0.00683)	(0.00645)
Business (0/1)	0.00381	0.00377	0.00370	0.00359	0.0154***	0.0113***	0.0128***	0.0112***
	(0.00647)	(0.00645)	(0.00632)	(0.00634)	(0.00141)	(0.00136)	(0.00106)	(0.00104)
Markets coverage	0.00252	0.00253	0.00235	0.00238	-0.00611***	-0.00335***	-0.00503***	-0.00361***
	(0.00232)	(0.00234)	(0.00220)	(0.00220)	(0.000500)	(0.000467)	(0.000538)	(0.000511)
Observations	12,171	12,171	12,171	12,171	12,171	12,171	12,171	12,171
Markets	39	39	39	39	39	39	39	39
ISP	34	34	34	34	34	34	34	34
FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Weak IV					92.81	52.94	28.98	30.81
Hansen p-val					0.358	0.420	0.330	0.347

Notes: Markets and ISP refer to the total number of unique markets and providers in the dataset. The time period is 2005Q4-2011Q1. See the data description for detailed information on the structure of the database. The market segmentation related to s_{jtg} is given by last-mile technologies (and outside option), namely: xDSL, cable, and wireless. Robust standard errors in parentheses are clustered on Internet service providers. Each specification includes time-, market- and ISP-fixed effects. The weak IV test corresponds to the Kleibergen-Paap test. *** p<0.01, ** p<0.05, * p<0.1.

Table 9: Nested logit demand model

	Full sample				Consolidated sample				Main cities			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Price	-0.0749***	-0.0756***	-0.0741***	-0.0722***	-0.0691***	-0.0671***	-0.0628***	-0.0573***	-0.0678***	-0.0588***	-0.0595***	-0.0541***
	(0.00317)	(0.00313)	(0.00404)	(0.00359)	(0.00232)	(0.00212)	(0.00183)	(0.00183)	(0.00154)	(0.00254)	(0.00197)	(0.00247)
$\ln(s_{jgt})$	0.200***	0.264***	0.273***	0.288***	0.323***	0.382***	0.405***	0.429***	0.406***	0.461***	0.468***	0.477***
	(0.0122)	(0.0141)	(0.0114)	(0.0115)	(0.00788)	(0.0133)	(0.0188)	(0.0199)	(0.0134)	(0.0174)	(0.0183)	(0.0206)
Cable (0/1)	2.453***	2.210***	2.342***	2.243***	2.579***	2.356***	2.460***	2.390***	2.870***	2.559***	2.736***	2.596***
	(0.0476)	(0.0555)	(0.0617)	(0.0616)	(0.0298)	(0.0457)	(0.0403)	(0.0419)	(0.0206)	(0.0251)	(0.0148)	(0.0238)
Xdsl (0/1)	2.347***	2.109***	2.227***	2.176***	2.576***	2.353***	2.452***	2.419***	2.731***	2.435***	2.573***	2.470***
	(0.0240)	(0.0260)	(0.0275)	(0.0305)	(0.0187)	(0.0285)	(0.0228)	(0.0228)	(0.0317)	(0.0237)	(0.0216)	(0.0252)
Broadband (0/1)		1.073***				0.920***				1.010***		
		(0.0381)				(0.0307)				(0.0505)		
Download speed			0.264***	0.665***			0.222***	0.525***			0.210***	0.617***
			(0.0307)	(0.0380)			(0.0216)	(0.0271)			(0.0166)	(0.0389)
Download^2				-0.0671***				-0.0543***				-0.0675***
				(0.00361)				(0.00290)				(0.00546)
Firm seniority	0.0876***	0.112***	0.0899***	0.0995***	0.0675***	0.0874***	0.0684***	0.0726***	0.122***	0.147***	0.121***	0.132***
	(0.00615)	(0.00592)	(0.00606)	(0.00543)	(0.00638)	(0.00518)	(0.00609)	(0.00554)	(0.00686)	(0.0102)	(0.00683)	(0.00645)
Business (0/1)	0.0187***	0.0162***	0.0174***	0.0158***	0.0166***	0.0139***	0.0138***	0.0128***	0.0154***	0.0113***	0.0128***	0.0112***
	(0.00193)	(0.00203)	(0.00172)	(0.00166)	(0.00113)	(0.00110)	(0.000895)	(0.000858)	(0.00141)	(0.00136)	(0.00106)	(0.00104)
Markets coverage	-0.00902***	-0.00806***	-0.00887***	-0.00845***	-0.00411***	-0.00344***	-0.00364***	-0.00308***	-0.00611***	-0.00335***	-0.00503***	-0.00361***
	(0.000492)	(0.000459)	(0.000693)	(0.000647)	(0.000499)	(0.000344)	(0.000464)	(0.000432)	(0.000500)	(0.000467)	(0.000538)	(0.000511)
Observations	38,070	38,070	38,070	38,070	26,618	26,618	26,618	26,618	12,171	12,171	12,171	12,171
FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Weak IV	103.1	109.7	39.47	38.89	83.39	65.72	41.01	35.57	92.81	52.94	28.98	30.81
Hansen p-val	0.502	0.445	0.427	0.407	0.333	0.329	0.381	0.381	0.358	0.420	0.330	0.347
Markets	595	595	595	595	294	294	294	294	39	39	39	39
Subscribers	1	1	1	1	0.997	0.997	0.997	0.997	0.874	0.874	0.874	0.874

Notes: Full sample is the raw dataset, consolidated sample is the data after dropping abnormal observations and plans with negligible market shares, and main-cities sample is the database used in the main analysis of this paper. The market segmentation related to s_{jtg} is given by last-mile technologies (and outside option), namely: xDSL, cable, and wireless. Robust standard errors in parentheses are clustered on Internet service providers. Each specification includes time-, market- and ISP-fixed effects. The weak IV test corresponds to the Kleibergen-Paap test. Markets denote the number of relevant markets covered by each sample, whereas the subscribers row shows the share of subscribers covered. *** p<0.01, ** p<0.05, * p<0.1.

Table 10: Nested logit demand model with different samples

6 Concluding remarks

In this paper, I have analyzed how the entry of a new Internet provider affects penetration rates and welfare in the market of residential Internet services in Colombia. I considered the entry of Telmex, a large telecom operator, in 2008 and used demand estimates, jointly with uncovered marginal costs, to conduct counterfactual analyses. The findings indicate that, due to the entry of Telmex, the adoption rate increased by 6 percentage points and consumer surplus rose by $7.2 million. Further, when examining the decomposition of the total effect, I find that the pure entry effect accounts, on average, for 62% of the total effect, whereas the remaining can be attributed to the adjustment of the menu of product offerings. There are potentially several policy implications stemming from these findings, especially for less developed countries, which would be interesting to study in future work.

I now briefly discuss several extensions that may help to overcome the limitations that were mentioned in the paper. First, I could conduct more controlled counterfactual experiments. For example, I could evaluate the effect of entry of Telmex in markets with a different number of incumbents (monopoly, duopoly, etc.). Alternatively, I could study the effect of entry of two or more providers (Telmex and other carriers) on the adoption rates and welfare. Second, the demand model presents limitations with regards to the substitution patterns. Even though these limitations have been, to some extent, mitigated by using the nested logit model, there is still room for improvement. In this regard, it would be interesting to estimate the random-coefficients logit model to control for unobserved consumer heterogeneity. This demand model generates more general substitution patterns (less dependence on the functional form) and could address the issue involving negative marginal costs. Finally, I reported neither standards errors nor confidence intervals for the computed entry effects. This raises concerns about the statistical validity of the results. To perform statistical inference, it would be interesting to implement parametric bootstrap using the price coefficient and the nesting parameter (Bjornerstedt and Verboven, 2014). In doing so, I could ensure the statistical significance of the results.

A Appendix

A.1 Descriptive statistics

	Adoption rate	Monthly fee	Download speed	Total ISP	Plan per ISP	Total markets	Obs
2005Q4	2.3	73	0.4	12	4.1	23	130
2006Q2	2.7	63.5	0.4	15	4.2	25	299
2006Q4	5.2	62.8	0.5	20	5.2	28	484
2007Q2	8.6	57.5	0.5	24	4.9	28	525
2007Q4	8.7	51.9	0.5	24	5.3	30	648
2008Q2	14.3	40	0.7	19	5.3	38	773
2008Q4	16.8	37.2	1.1	21	4.9	39	811
2009Q1	17.6	33.6	1.2	20	5.1	39	871
2009Q2	18.6	33.2	1.2	18	6.2	39	1058
2009Q3	18.6	34.3	1.3	19	6	39	1079
2009Q4	19	31.7	1.4	20	5.8	39	990
2010Q1	18.6	29.2	1.6	19	5.8	39	886
2010Q2	20.5	31.4	1.8	20	6.1	39	855
2010Q3	20.9	31.6	1.8	20	6.3	39	903
2010Q4	21.9	29.4	2	20	6.7	39	946
2011Q1	22.4	27.3	2.2	17	7.1	39	913

Notes: Adoption rate is the total number of subscribers(households) in Colombia divided by the potential market size. Average monthly fee is in US dollars, whereas average download is expressed in Mbps. The column plan per ISP shows the average number of plans offered by each ISP in every market. The last column shows the number of observations (market-ISP-technology-speed combination) for each period.

Table 11: Evolution of main variables over time

	Mean	Std. Dev	Min	Max
Income	388.84	73.48	218.99	1147.43
Education	4.28	0.18	3.68	4.82
Age	29.87	2.12	21.50	33.88
Children	1.33	0.27	0.96	2.47
HH members	3.77	0.40	3.04	5.58

Notes: This table provides information on demographics. The unit of observation is the market-period combination. Income (in US Dollar), education(from 1 - 6, where 1 is no education, 4 is lower secondary education and 6 is tertiary education) and age (years) are averages across individuals. Children (number of individuals with less than 18 years) and household (HH) members correspond to average across households. The number of observations is 562. The source is the household survey Gran Encuesta Integrada de Hogares (GEIH).

Table 12: Demographics

A.2 Reduced-form evidence

	Control group: Untreated and treated markets in 2008Q4			Control group: Treated markets in 2008Q4		
	(1)	(2)	(3)	(4)	(5)	(6)
Entry 2008Q2×Post	-0.112***			-0.0780***		
	(0.0289)			(0.0293)		
Entry 2008Q2×Placebo post		-0.0319	-0.0692**		-0.0194	-0.0239
		(0.0316)	(0.0331)		(0.0357)	(0.0348)
Observations	2,859	2,086	2,086	2,196	1,592	1,592
R-squared	0.723	0.732	0.728	0.719	0.705	0.705
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Mkt FE	Yes	Yes	Yes	Yes	Yes	Yes
ISP FE	Yes	Yes	Yes	Yes	Yes	Yes
Mkts	39	31	31	20	19	19
ISPs	29	27	27	27	25	25
Periods	6	5	5	6	5	5
Placebo post		2006Q4	2007Q2		2006Q4	2007Q2

Notes: This table provides the results of evaluating the effect of the first entry of Telmex in 2008Q2 using data prior to this period. In columns (1)-(3), the control groups are defined by untreated markets and markets that were treated in 2008Q4. In contrast, columns (4)-(6) compare treated units with markets that were treated in 2008Q4. The validation tests are reported in columns (2)-(3) and (5)-(6). These results use data prior to the first entry of Telmex in 2008Q2. Two placebo models are conducted assuming different timing for the entry episodes. The dependent variable is log(price). Control variables (not reported in the table) include: download speed (and quadratic term); indicator variable for broadband connections; indicator variables for last-mile technologies; characteristics of the ISP (seniority, business services and market coverage); and municipality-specific demographic variables. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 13: Reduced-form evidence: Cohort 2008Q2

	Dependent variable: Log(price)				
				Before 2008Q2	
	(1)	(2)	(3)	(4)	(5)
Entry×Post	-0.0714***	-0.0459***			
	(0.0159)	(0.0157)			
Entry×Trend			-0.0121		
			(0.00778)		
Entry×Placebo post				-0.0704	-0.0953**
				(0.0478)	(0.0432)
Observations	12,171	12,171	3,689	2,086	2,086
R-squared	0.608	0.624	0.633	0.732	0.732
Time FE	Yes	Yes	Yes	Yes	Yes
Mkt FE	Yes	Yes	Yes	Yes	Yes
ISP FE	Yes	Yes	Yes	Yes	Yes
ISP Trend	No	Yes	-	-	-
Mkts	39	39	38	31	31
ISPs	34	34	30	27	27
Periods	16	16	16	5	5
Note			Post=0	Entry:2006Q4	Entry:2007Q2

Notes: Control variables (not reported in the table) include: download speed (and quadratic term); indicator variable for broadband connections; indicator variables for last-mile technologies; characteristics of the ISP (seniority, business services and market coverage); and municipality-specific demographic variables. Column (2) adds an ISP-specific time trend to the baseline model (1). This allows control and treatment groups to follow different trends and constitutes a validation of the DD identification strategy (Angrist and Pischke, 2009). Column (3) compares trends between treatment and control groups before any entry episode. Columns (4)-(5) use data prior to the first entry of Telmex in 2008Q2. Two placebo models are conducted assuming different timing for the entry episodes. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 14: Common trends: Price

	Dependent variable: Log(# plans)				
				Before 2008Q2	
	(1)	(2)	(3)	(4)	(5)
Entry×Post	0.140***	0.169***			
	(0.0496)	(0.0507)			
Entry×Trend			0.0490***		
			(0.0174)		
Entry×Placebo post				-0.238	0.0672
				(0.178)	(0.187)
Observations	2,134	2,134	774	567	567
R-squared	0.607	0.647	0.636	0.614	0.613
Time FE	Yes	Yes	Yes	Yes	Yes
Mkt FE	Yes	Yes	Yes	Yes	Yes
ISP FE	Yes	Yes	Yes	Yes	Yes
ISP Trend	No	Yes	-	-	-
Mkts	39	39	38	38	38
ISPs	34	34	30	29	29
Periods	16	16	16	7	7
Note			Post=0	Entry:2006Q4	Entry:2007Q2

Notes: The sample is at the period-market-ISP level. The control variables (not reported) represent averages of the Internet plans served by the ISPs. In particular, the control variables include: download speed (and quadratic term); indicator variables for last-mile technologies; characteristics of the ISP (seniority, business services and market coverage); and municipality-specific demographic variables. Column (2) adds an ISP-specific time trend to the baseline model (1). This allows control and treatment groups to follow different trends and constitutes a validation of the DD identification strategy (Angrist and Pischke, 2009). Column (3) compares trends between treatment and control groups before any entry episode. Columns (4)-(5) use data prior to the first entry of Telmex in 2008Q2. Two placebo models are conducted assuming different timing for the entry episodes. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 15: Common trends: Number of plans per ISP

A.3 Counterfactual

Scenario I Telmex New Plans (*Status quo*) Adopt.(%): 20.6 CS: 12.73 PS: 22.99	**Scenario III** No Telmex New Plans Adopt.(%): 16.81 CS: 7.97 PS: 18.99
Scenario II Telmex Old Plans Adopt.(%): 18.37 CS: 9.74 PS: 20.71	**Scenario IV** No Telmex Old Plans Adopt.(%): 14.28 CS: 5.53 PS: 16.17

Table 16: Counterfactual analysis: 4 scenarios 2008Q2

	Telmex		No Telmex		Total	Decomposition (%)	
	New	Old	New	Old	Effect	Plans	Telmex
Year	plans (I)	plans (II)	plans (III)	plans (IV)	(I-IV)	effect	effect
2008	21.83	19.33	17.56	14.71	7.13	35.18	64.82
2009	11.26	11.15	10.92	10.81	0.46	24.02	75.98
2010	12.21	11.86	12.12	11.77	0.44	78.7	21.3

Notes: The first four columns show the outcomes of 4 different scenarios that differ with respect to the entry of the provider Telmex and the offering of new or old plans. The scenario (I) is the status quo in 2008Q2. As for scenarios (II) and (IV), the set of old Internet plans is formed using the offers of the last quarter of 2007. Total effect (Column 5) is the difference between scenario (I) and (IV). The last two columns decompose (in percentage) the total effect into the plans effect (I-II) and the pure entry effect (II-IV). The number of markets analyzed is 30.

Table 17: Counterfactual analysis: Effect decomposition by years.

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