Competition with endogenous and exogenous switching costs

Stony Brook University

Tilsa Oré Mónago *

(for the latest version, click `here`)

October, 2017

Abstract

This paper presents a general theoretical framework for dynamic competition under the presence of two types of switching costs: endogenous, which are set by providers (fees), and exogenous, which are specific to consumers. In a two-period game, two providers compete in prices and switching fees, and can price discriminate between old (loyal) and new (switchers) consumers.
I found there are symmetric subgame perfect equilibria in pure strategies, where the market is split equally between providers and a third of the population switch in the second period. Equilibrium prices and switching fees are not uniquely determined, but total discounted payoffs for providers and consumers are. These total payoffs are unaffected by the ability to set switching fees, but are directly affected by individual (exogenous) switching costs. Switching fees are neutral; they only intensify intertemporal price variation and, therefore, affect intertemporal payoffs by accentuating the trade-off between present and future benefits. These results explain the coexistence of competing providers that set and dismiss switching fees. They also suggest that regulatory policies should reduce individual switching costs (such as number portability, standardization or compatibility) rather than eliminate or regulate switching fees. Finally, I present empirical evidence from the Peruvian mobile telecommunications market that supports a prediction from this theoretical model.

Keywords: Dynamic competition, duopoly, switching costs, introductory offers.

1 Introduction

Switching costs (SC) affect consumers free decision to change providers of certain product or service. These costs may be related to learning (software usage), information (medical history of patients for example), transactions (paperwork to terminate and

*I would like to thank Yair Tauman and Sandro Brusco for their patience, guidance and constant help; to Yiyi Zhou, Ting Liu, Roberto Burquet and John Hillas for the insightful comments during the workshops, and Alejandro Melo for the productive discussions in Stony Brook. Special thanks to Guy Arie for his valuable feedback and comments. Thanks to Greg Duncan, Fahad Khalil, Jacques Lawarrée, Quan Wen and Xu Tan for their comments and suggestions in the Brown bag Microeconomics Workshops at the University of Washington, Seattle. I am also deeply grateful to the comments received from the participants of the IIOC 2017 in Boston, the International Game Theory Conference 2017 at Stony Brook, and the Econometric Society Summer School 2017 at Seoul, South Korea. Errors and mistakes are my own. My e-mail address is tilsa.oremonago@stonybrook.edu.

initiate the consumption of certain service), or due to direct firms' practices to keep consumers by charging early contract termination fees (ETF) or by offering coupons and discounts to frequent consumers.

Two types of switching costs can be distinguished: those in the form of switching fees or any other lock-in mechanism, which are set by firms; and those that are specific to individuals.[1] The latter, which is referred in the literature as exogenous SC (from the providers' viewpoint), affects directly to consumers, and providers do not set their level. These type of SC may include psychological costs of switching, learning costs, the opportunity cost of time spent on paperwork, among others.[2]

Understanding the nature of SC and its impact on market outcomes and equilibrium conditions is important for researchers and policy makers. This given their presumed detrimental effect by increasing average prices or even changing price structures (NERA, 2003). Many have been the regulatory attempts to reduce SC; in particular, in the telecommunications industry. Thus, number portability has been widely implemented since late 90's. More recently, in Latin America, regulatory agencies targeted the sales of locked mobile handsets. Regulations also targeted switching fees; in the U.S.A. in April 2016, the FCC banned ETF in business data services; in Peru, regulations bounded ETF and restrict contracts' duration. Nonetheless, an interesting observation is the coexistence of competing providers that set ETF with those that dismiss its use.

Most of the theoretical models include only exogenous switching costs in their analysis, few as Caminal and Matutes (1990) and Shi (2013) add endogenous switching costs in the form of discounts, Chen (1997) explains poaching practices with exogenous switching costs, Fabra and Garcia (2015) and Cabral (2016) account for endogenous switching costs in their extended infinite-period models.

This paper contributes to the literature by analyzing the effect of exogenous and endogenous switching costs. It is based on Chen (1997) but differs from it by distinguishing endogenous from exogenous switching costs, adding an individual taste shock and letting the endogenous switching costs level be set in the initial period and not in the switching period (second period). It also differs from Shi (2013) by considering introductory offers and making exogenous switching cost different across consumers. My objective is to understand what determines the endogenous component (switching fee), how its strategic use affects the market outcomes and consumer welfare, why some companies would dismiss setting switching fees, and how a reduction of the exogenous component (exogenous switching costs) impacts the market. This would also allow for improved policy recommendations.

I develop a theoretical framework for a dynamic competition under the presence of switching costs, where two providers in a subscription market compete in prices and

[1]Examples of endogenous SC include the early termination fees in the telecommunications industry; the loyalty programs in the airline market; or cash rewards program in the credit card market. In this particular paper, I focus in the existence of switching fees in the form of ETF.

[2]As an example, we can think of the extra cost of getting an unlocked handset or the extra costs of unlocking a handset by a technician (locked phones are widely seen in mobile telecommunication market, and can be thought as given). Also incurred costs of security clearance paperwork relevant for the labor market in developing countries; or the time spent to get a medical examination and report to prove health condition in the insurance market.

strategically use switching fees, while consumers face additionally an exogenous individual switching cost. I consider a two-period game where providers simultaneously set prices and switching fees in the first period; in the second period, providers use introductory offers since they can distinguish between old consumers and newcomers, to attract new consumers (rival's consumers).

Using a linear probability approach in a random utility setting, this model allows for heterogeneity across consumers in two dimensions, individual relative preferences and individual switching costs. Focusing on equilibria in pure strategies, I find symmetric subgame perfect equilibria, where the market is split according to consumers taste parameters in the first period, and third of the population switches in the second period. In the extended version, where providers invest on influence tastes, the market is split equally between providers. Equilibrium tuples of prices and switching fees are not uniquely determined, but providers' profits and consumers' payoffs are.

An important result is that switching fees are neutral; the presence of switching fees (endogenous to the providers) only impact intertemporal payoffs with countervailing effects, leaving multi-period payoffs unaffected. This actually would explain the observation of companies dismissing ETF, which also agrees with the finding of Cullen et al. (2016).

Another important finding is that second-period prices are increasing in individual switching costs, and loyal consumers are charged higher than newcomers (switchers). Moreover, since both, social welfare and consumer surplus are negatively affected by the exogenous individual switching cost parameter, the model suggests that lowering exogenous switching costs (by a regulatory change for example) would lead to higher consumer surplus and bigger social welfare.

Finally, I also provide with some empirical evidence for the Peruvian mobile telecommunications market that supports a prediction from this model. In particular, given the predicted effect of exogenous individual switching costs on second period prices, an increase in demand is expected from a reduction of this type of switching costs. Taking advantage of a major reform – the unlocked handset policy– implemented in Peru in early 2015, and using longitudinal survey data and firm level data for the period 2013-2015, I empirically test such prediction. I find that the unlocked handset policy (reduction of exogenous switching costs) generated a 33% increase of the demand of mobile services (measured as minutes of call) of consumers who switched and, moreover, I find that any change of current consumers' status (consumption plan or provider) would induce an additional 28% increase in their demand for the service.

This paper is organized as follows: Section 2 presents the related literature, Section 3 presents the model in detail, Section 4 presents the equilibrium analysis, Section 5 presents an empirical application of the model and Section 6 presents the conclusions.

2 Related literature

Switching costs are usually studied by dynamic price models, and modeled by two-period models (Klemperer, 1983, 1987b,a; Farrel and Shapiro, 1988; Caminal and Matutes, 1990; Beggs and Klemperer, 1992; Padilla, 1995; To, 1996; Shaffer and Zhang, 2000), many repeated finite periods and infinite period models (Taylor, 2003; Dube et al., 2009; Pearcy, 2011; Cabral, 2012; Arie and Grieco, 2014; Fabra and Garcia, 2015; Cabral, 2016). Some explain market entry under the presence of switching costs (Klemperer, 1988; Farrel and Shapiro, 1988; Beggs and Klemperer, 1992; Wang and Wen, 1998), but most of them considerate only one type of switching costs, either exogenous or endogenous similar across consumers. Recently, Biglaiser et al. (2013, 2016) accounted for consumer heterogeneity in terms of switching costs, but they abstract from the presence of endogenous switching costs.

The effect of switching costs on competition is ambiguous. Early literature shows that switching costs increase average prices and profits, basically due to a "bargain-then-ripoff" strategy; while recent literature shows that low switching costs can be pro-competitive, they may give providers short-term incentives to lower prices and profits.

Models that include switchers and a replacement rate of established consumers (Farrel and Shapiro, 1988; Padilla, 1995; To, 1996; Cabral, 2012), in general solve for Markov perfect equilibria and get similar results. Farrel and Shapiro (1988) finds that incumbents supply only to their loyal/attached consumers and the entrants serve the newcomers. However, switching costs generate excessive entry, which creates inefficiencies in the market. In Padilla (1995), switching costs generate higher prices and profits in every period, and prices increase with firms' customer base, which also implies more difficulties in sustaining tacit collusion. [3]

Fudenberg and Tirole (2000) and Chen (1997) focuses more on the strategies used by firms to attract customers from their competitors. Toolsema (2009) adds an interesting approach by differentiating intra and interfirm switching costs, but she restricts her analysis to a static monopoly pricing structure. Shapiro (1999) deals directly with the exclusivity of services within industries with network effects.

Although switching costs are usually discussed in dynamic models, a static approach is also used (Klemperer, 1988; Shaffer and Zhang, 2000). Klemperer (1988) analyzes firms' entry decisions in markets with switching costs. According to that model, when switching costs are unavoidable, entry is found to be socially undesirable due to the welfare losses caused by the switching costs that consumers have to face and the incumbents' output that would have been efficiently provided with no entry. Shaffer and Zhang (2000) focus their analysis to the effect of switching costs into subscription markets under symmetric and asymmetric firms; they find that when markets are symmetric it is optimal a pay-to-switch price strategy, while when markets are asymmetric, it is more profitable use a pay-to-stay strategy. Using two-period models, Beggs and Klemperer (1992) show that switching costs lead to higher equilibrium prices and higher profits, thus markets with switching costs become more attractive to the entry of new firms, and that market shares would converge to the same rate if firms exhibit similar costs. This may be the reason why switching costs reduce demand elasticity.

By modeling a two-period economy that produces a homogeneous good, Klemperer (1987b) finds that switching costs lead to increased competition in the first period to

[3] Switching costs would make punishments less severe in collusive agreements.

get the larger portion of the market in order to maximize second-period rents by charging high prices top loyal consumers.[4] [5] Competition intensity, however, is reduced in the following period, when also firms produce less. Thus, welfare is expected to fall due to switching costs. In a similar study, but with differentiated goods, Klemperer (1987a) finds that the effect on competition is ambiguous for the first period, but damaging in the second period due to the firms' incentive to take advantage of their loyal established consumers.

More recently, using an infinite horizon approach, Dube et al. (2009) show a negative relationship between switching costs and prices in markets with differentiated products; their result suggest consumers becomes more valuable with switching costs, so firms would compete more aggresively to attract them. This results are shared with Fabra and Garcia (2015), who find switching costs becomes pro-competitive in the long-run when market shares tend to be symmetric, when market structure is asymmetric then switching costs lead to higher prices. Under the absence of price discrimination between loyal and non-loyal consumers, Arie and Grieco (2014) show switching costs have a larger compensating effect that lead firms to reduce prices, instead of increasing them, to attract switchers from the rival. A common assumption in these models is that either are consumers homogeneous or they face same switching costs. On that aspect, Biglaiser et al. (2013, 2016) explicitly add switching costs heterogeneity in their analysis under the context of market entry. They distinguish a low and a high switching cost type of consumers, and find that a large presence of consumers with low switching costs favors the incumbent by making more difficult to the entrant to attract the valuable high switching cost type consumers.

One of the earliest references on endogenous switching costs is given by Aghion and Bolton (1987), who found that locked-in or esclusive contracts are used to restrict market entry; moreover, buyers would only engaged in transactions with the entrant if they get compensated by lower prices and they covered their switching fees. Thus, these contracts serve to extract the surplus the entrant could generate if entry would have happen. Caminal and Matutes (1990) present a duopoly model with endogenous switching costs and differentiated product. They consider pricing practices to retain customers as well pre-commitment to prices or coupons in the initial period. They find that price commitment enhances competition, while coupons shrink it. Firms would prefer switching costs to be absent, but since their next period rents depend on retained consumers, they would usually use switching costs in the form of coupons or discounts. Also based on an infinite-period model, Cabral (2012) finds conditions for switching costs to affect prices in opposite directions. According to the study, switching costs in markets already competitive strengthen the competitive behavior by intensifying competition for new customers. However in markets with lower initial competition, switching costs make the market even less competitive because the switching costs' effect on reinforcing market power of larger firms dominates.

In this paper, I consider both, exogenous and endogenous switching costs in my anal-

[4]Firms fiercely compete for attracting customers in the first period, even when that means setting prices below costs. This happens because they would charge monopoly prices in the second period to their loyal consumers.

[5]Farrel (1986) shows that firms with larger market share in the first period charge higher prices in the second period, up to the level that the firm still gets the larger market share in the second period.

ysis, and consider consumer heterogeneity in two dimensions, relative preferences and exogenous individual switching costs. In particular, the model is based on Chen (1997) but differs from it by adding an individual taste shock and letting the endogenous switching costs level be set in the initial period and not in the switching period (second period). It also differs from Shi (2013) by considering introductory offers and making exogenous switching cost different across consumers. As in Biglaiser et al. (2016), I deal with heterogeneous switching costs, but consider in addition the coexistence of exogenous and endogenous switching costs, add introductory offers and, in an extended version, add marketing effort to influence consumer preferences.

3 A model on competition with switching costs

I consider a two period model, where there is a unit mass of consumers, who are heterogeneous in their preferences and idiosyncratic switching cost. There are two competing providers A and B, who offer substitute services to their consumers.

For simplicity, I assume that providers' marginal cost is zero.The providers operate in two periods and have the same discount rate $\delta \in (0, 1]$. A contract with provider $i \in \{A, B\}$ in period 1 is a pair (T_i, s_i), where T_i is the price a consumer has to pay for the first period unlimited service of i, and s_i is a switching fee a consumer of i will have to pay to provider i if he switches in the second period from i to j, $j \neq i$ (an early termination fee ETF). A contract in period 2 with provider $i \in \{A, B\}$ specifies a price T_{ii} a consumer that chose i in both periods has to pay for the second period unlimited service of i; and a price T_{ji} a consumer that switched providers from j to i has to pay for the second period service of i.[6]

From the demand side, and following a discrete choice approach, consumers have per period linear indirect utility (payoff) functions, have rational expectations and have the same discount rate $\delta \in (0, 1]$.[7] Every consumer has a per period valuation v for the service, which is assumed to be big enough so the market is covered. Also every consumer k receives a taste shock σ_k –an idiosyncratic relative preference for provider A respect to B – revealed in the first period that last only that period; in this regard, I follow the standard literature and assume non-persistent consumers' preferences. σ_k is uniformly distributed on the interval $[-\theta_1, \theta_2]$ and has density function $h(\sigma_k)$. [8] Providers only know the distribution of idiosyncratic variables.

In the second period, the source of heterogeneity comes from the presence of an individual specific exogenous switching cost, x_k, which is uniformly distributed on the interval $[0, \omega]$ with density function $f(x)$. This exogenous switching cost x_k is learned by the consumers at the beginning of the second period and occurs independently of the first period shock. This exogenous cost refers to learning costs or costs (time, money, etc.) incurred by, for instance, canceling and account or unlocking a handset in the mobile telecommunications industry; cost that are unknown in the first period. This

[6]from here on, I will refer to T_{ii} and T_{ji} as the prices for loyal consumers of provider i and prices for switchers to provider i.

[7]I took the approach reviewed in the section 2.5 of Anderson et al. (1992), also used by Cabral (2016).

[8]This relative preference is such that if $\sigma_k \geq 0$, then a consumer likes A more than B, and if $\sigma_k < 0$ B is preferred over A.

cost shock captures the uncertainty consumers face about the future, but are considered within their expected payoff maximization.[9]

Consumers then face two types of switching costs, the endogenous one that is set by the firm and appears as a fee and it basically refers to transfers from consumers to providers; and the exogenous one that are individual specific to consumers and it refers basically to pure deadweigh losses.[10]

In the first period, after observing $((s_A, T_A), (s_B, T_B))$, every consumer chooses a provider from $\{A, B\}$. Then, given their chosen provider in the first period and the new prices in the second period, consumers decide either to stay with their provider i, or to switch to the other provider and pay a switching fee s_i, $i \in \{A, B\}$ to their previous provider and incur in additional switching costs x_k.

Timeline of the game

The game timeline is described below:

$t = 1$		$t = 2$	
Stage 1	Stage 2	Stage 1	Stage 2
Providers set flat prices (T_A,T_B) and switching fees (s_A,s_B)	Consumers learn σ_{ik}, then given prices and preferences they choose their provider	Providers set new flat prices (T_{AA},T_{BA}) and (T_{BB},T_{AB})	Consumers learn x_k, then given new prices, they decide to stay or to switch

In the first stage of the first period, providers choose simultaneously (T_A, s_A) and (T_B, s_B). In the second stage, consumers observe firms' choices and simultaneously choose provider (A, B).

In the first stage of the second period, providers choose simultaneously their prices for newcomers, T_{BA} and T_{AB}, and for loyal consumers, T_{AA} and T_{BB}. Providers do not commit to keep previous period prices, but they commit in terms of switching fees only. Consumers observe the new prices, and simultaneously decide whether to stay with their providers or to switch providers.

Throughout the paper I keep this limited commitment assumption. The lack of commitment is actually sensible in my model, given that I am not accounting for quality

[9]For simplicity, I focus on the analysis when this cost shock is realized in the second period, rather than in the first. If consumers would know their switching cost type at the beginning of the game, consumer's decisions may become interdependent to the other consumers. Under the absence of endogenous switching costs, Biglaiser et al. (2016) show that high switching cost consumer type free rides and will have the incentive to buy from the provider with largest share of low-SC consumers type, from which they expect lower second period prices and face higher first period price.

[10]I will show that providers' profits will depend positively on the exogenous switching cost parameter, for which it is sensible to argue they will have incentives to influence on it level, but for this moment I abstract from that situation. The model could be extended by endogeneizing the exogenous switching cost parameter, but I leave that for future research.

of the service in the model, and therefore utility of consumers are not fully specified. Thus, full price commitment would not be a reliable assumption if I abstract from quality valuations.

The Payoffs

Consumers

In period 1, the payoff of a consumer k of firm A is

$$R_{1Ak} = v + \sigma_k - T_A$$

and of a consumer k of firm B is

$$R_{1Bk} = v - \sigma_k - T_B$$

In period 2, the payoff of a consumer that chose firm $i \in \{A, B\}$ in period 1 is

$$R^i_{2k} = \max\{R_{ii,k}, R_{ij,k}\}$$

where,

$$\begin{aligned} R_{ii,k} &= v - T_{ii} && \text{if the consumer chose firm } i \text{ also in the first period} \\ R_{ij,k} &= v - T_{ij} - s_i - x_k && \text{if the consumer switched providers from } i \text{ to } j \end{aligned}$$

The decision variable in the first period is given by the idiosyncratic relative taste parameter, and in the second period the decision variable is the exogenous switching cost.

Thus, the multi-period net payoff of a consumer k who chooses firm i in period 1 is

$$R^i_k = R_{1ik} + \delta E_x[R^i_{2k}] \tag{1}$$

Providers

I denote α and $(1-\alpha)$ the first period market shares of providers A and B, respectively. Likewise, in the second period, n_{ii} refers the share of consumers that consume from i in both periods, and n_{ij}, to the share of consumers that switched from i to j.

In the second period, providers‘ profits come from loyal consumers, newcomers and the switching fee collected from switchers that left. Thus, second period profits are given by

$$\pi_{2i} = n_{ii}T_{ii} + n_{ji}T_{ji} + n_{ij}s_i \quad \forall i, j \in \{A, B\}$$

The first period payoffs are $\pi_{1A} = \alpha T_A$ and $\pi_{1B} = (1-\alpha)T_A$, so provider i solves:

$$\max_{T_i, s_i} \pi_i = \pi_{1i} + \delta \pi_{2i} \tag{2}$$

The game is structured such that consumers are not treated as players. Consumers' behavior are worked as a function of all prices and used to define firms' payoff functions. Thus, I solve this game using backward induction, so I start finding the second-period equilibrium, and then continue with the first-period equilibrium in pure strategies.

3.1 The Second Period Equilibrium

Given their first period choices of provider and the second period new prices, consumers make their decision to switch or stay with their current provider.

A consumer k stays with his first-period provider if and only if his net payoff with this provider is at least as high as with the other (net of switching fee and costs), that means when $R_{ii} \geq R_{ij}$ (I omit the consumer index k for simplicity). Therefore, the probability that a consumer chooses to stay with his first period provider i is:

$$\begin{aligned}
Pr[stay \;\; in \;\; i|i] &= Pr(R_{ii} \geq R_{ij}) \\
&= Pr(x \geq T_{ii} - T_{ij} - s_i) \\
&= Pr(x \geq x_i) \\
Pr[switch \;\; to \;\; j|i] &= 1 - Pr[stay \;\; in \;\; i|i]
\end{aligned}$$

First, for consumers that chose A as their first-period provider, we understand they revealed their relative preference for A.[11] Within this group, a consumer will be indifferent between staying in A (staying loyal) and switching to B if x is such that $R_{AA} = R_{AB}$ and $x \in [0, \omega]$, which means

$$\begin{gathered}
v - T_{AA} = v - T_{AB} - s_A - x \\
x = (T_{AA} - T_{AB} - s_A) \\
x = x_A
\end{gathered}$$

From this last equation, x_A represent the savings any consumer get by switching (the benefit of switching), while x is the exogenous idiosyncratic cost of switching. Thus, x_A represents exogenous switching cost level for the A's consumer who is indifferent between staying in A or switching to B, provided that $x_A \in [0, \omega]$. If $x_A > \omega$, then the benefit of switching surpasses the maximum idiosyncratic cost, therefore every consumer of A prefers to switch to B. If $x_A < 0$, then the benefit of switching is lower than the minimum idiosyncratic cost for an A's consumer, therefore every consumer of A prefers to stay in A. If $0 \leq x_A \leq \omega$, then consumers with idiosyncratic exogenous switching cost x above x_A will stay with A and those consumers with idiosyncratic exogenous switching cost below x_A will switch to B.

Similar analysis holds for the case of consumers that chose B as their first period provider. Hence, a consumer will be indifferent between staying and switching when $R_{BB} = R_{BA}$, thus $x_B = T_{BB} - T_{BA} - s_B$ and $x = x_B$. Thus, consumers will stay or switch given that $0 \leq x_B \leq \omega$.

In general, provided that $x_i \in [0, \omega]$, the choice probabilities times the first period market share – α for A and $(1 - \alpha)$ for B– are the demands of loyal consumers and switchers from each firm.

[11] I assume that in the second period consumers do not have any other preference shock neither they keep the previous period's one.

$$n_{AA} = \alpha \int_{x_A}^{\omega} \frac{1}{\omega} dx = \frac{\omega - (T_{AA} - T_{AB} - s_A)}{\omega}$$
$$n_{AB} = \alpha \int_{0}^{x_A} \frac{1}{\omega} dx = \frac{T_{AA} - T_{AB} - s_A}{\omega}$$
$$n_{BB} = (1-\alpha) \int_{x_B}^{\omega} \frac{1}{\omega} dx = \frac{\omega - (T_{BB} - T_{BA} - s_B)}{\omega}$$
$$n_{BA} = (1-\alpha) \int_{0}^{x_B} \frac{1}{\omega} dx = \frac{T_{BB} - T_{BA} - s_B}{\omega}$$

Therefore, taking into account the values of choice probabilities, and provided that $x_i \in [0, \omega]$, second period profits are

$$\pi_{2A} = \alpha T_{AA} - \frac{\alpha}{\omega}(T_{AA} - T_{AB} - s_A)(T_{AA} - s_A) + \frac{(1-\alpha)}{\omega} T_{BA}(T_{BB} - T_{BA} - s_B) \tag{3}$$

$$\pi_{2B} = (1-\alpha) T_{BB} - \frac{(1-\alpha)}{\omega}(T_{BB} - T_{BA} - s_B)(T_{BB} - s_B) + \frac{\alpha}{\omega} T_{AB}(T_{AA} - T_{AB} - s_A) \tag{4}$$

Profit functions are quadratic and concave in their arguments (prices), so maximizing over prices (T_{ii} and T_{ji}) we expect an interior solution.[12]

Solving for the second-period equilibrium by using the first order conditions, the following is the unique solution. These results also satisfy the second order conditions:

$$T^*_{AA} = \frac{2}{3}\omega + s_A \tag{5}$$

$$T^*_{BB} = \frac{2}{3}\omega + s_B \tag{6}$$

$$T^*_{BA} = T^*_{AB} = \frac{\omega}{3} \tag{7}$$

The equilibrium outcome for second-period prices do not depend on first-period market shares due to discriminatory pricing towards loyal consumers and switchers. These prices are increasing in the exogenous switching cost ω, and the endogenous switching fee s_i only affects the prices that loyal consumers face.[13] Indeed, loyal consumers end up paying switching fees as part of their prices.

Also, given these values, second-period shares are $n_{AA} = \frac{2}{3}\alpha$, $n_{AB} = \frac{1}{3}\alpha$, similarly, $n_{BB} = \frac{2}{3}(1-\alpha)$, $n_{BA} = \frac{1}{3}(1-\alpha)$, which clearly indicates that a third of first period consumers switches in the second period. This is a similar result to Chen (1997) for the case of paying-consumers-to-switch.

[12] The second derivatives are negative: $\frac{\partial^2 \pi_{2A}}{\partial {T_{AA}}^2} = -\frac{2\alpha}{\omega} < 0$, and $\frac{\partial^2 \pi_{2A}}{\partial {T_{BA}}^2} = -\frac{2(1-\alpha)}{\omega} < 0$. Likewise, $\frac{\partial^2 \pi_{2B}}{\partial {T_{AB}}^2} = -\frac{2\alpha}{\omega} < 0$, and $\frac{\partial^2 \pi_{2B}}{\partial {T_{BB}}^2} = -\frac{2(1-\alpha)}{\omega} < 0$

[13] Second period prices are positively affected by exogenous switching cost: $\frac{\partial T_{ii}}{\partial \omega} = \frac{2}{3} > 0$ and $\frac{\partial T_{ij}}{\partial \omega} = \frac{1}{3} > 0$

Proposition 1. *Provided that $x_A, x_B \in [0, \omega]$, for every market share α, there exists a unique Nash equilibrium of the second period subgame, where second-period prices do not depend on first-period market shares, the endogenous switching fee s_i only affects the prices that loyal consumers face, and a third of the population switches.*

The equilibrium in proposition 1 is a second period Nash equilibrium in the subgame and the proof is provided in the appendix. Now, using (5), (6), and (7) into (3) and (4) profits are

$$\pi_{2A}^* = \frac{\omega}{9}(1+3\alpha) + \alpha s_A \tag{8}$$

$$\pi_{2B}^* = \frac{\omega}{9}(1+3(1-\alpha)) + (1-\alpha)s_B \tag{9}$$

As expected, second period profits depend heavily in their first market share, which may imply higher incentives of providers to lock-in consumers with higher switching fees. It is easy to check that $\frac{\partial \pi_{2A}^*}{\partial \alpha} = \frac{\omega}{3} + s_A > 0$ if $s_A \geq -\frac{\omega}{3}$.

3.2 The First Period

In the first period, consumers make a choice between providers, therefore, the payoff of a consumer k will be given by :

$$\begin{aligned} R_{1Ak} &= v + \sigma_k - T_A \\ R_{1Bk} &= v - \sigma_k - T_B \end{aligned}$$

where σ_k is the relative preference for firm A respect to firm B , and is uniformly distributed on the interval $[-\theta_1, \theta_2]$.

In the first period, consumers take decisions based on heir multiperiod payoffs. Thus, each consumer compare R^A vs. R^B

$$\begin{aligned} R_A &= R_{1A} + \delta E_x[R_{2A}] \\ R_B &= R_{1B} + \delta E_x[R_{2B}] \end{aligned}$$

Therefore, [14]

$$\begin{aligned} R_A &= v + \sigma_A - T_A + \delta(v - \tfrac{11}{18}\omega - s_A) \\ R_B &= v - \sigma_A - T_B + \delta(v - \tfrac{11}{18}\omega - s_B) \end{aligned}$$

Thus,

$$Pr[choose \ \ A] = Pr[R_A \geq R_B] = Pr[\sigma \geq \hat{\sigma}]$$

A consumer is indifferent between A and B when $\hat{\sigma} = \frac{T_A - T_B + \delta(s_A - s_B)}{2}$, hence, provided that $\hat{\sigma} \in [-\theta_1, \theta_2]$, and that $\sigma \sim U[-\theta_1, \theta_2]$ with density function $h(\sigma)$, we get the choice probabilities.
Since we have a unit mass of consumers, these probabilities actually give us the first-period market shares of the providers, therefore:[15]

[14] We get the expected second period payoffs using the distribution of exogenous switching costs x_k. The calculation of expected second period consumer surplus is shown in the appendix.

[15] Recall that for the indifferent consumer $\sigma = \hat{\sigma}$, so we can solve for $\hat{\sigma}$.

$$\alpha = \int_{\hat{\sigma}}^{\theta_2} h(\sigma)d\sigma = \frac{1}{2(\theta_2+\theta_1)}(2\theta_2 - (T_A - T_B + \delta(s_A - s_B)))$$

and,

$$(1-\alpha) = \int_{-\theta_1}^{\hat{\sigma}} h(\sigma)d\sigma = \frac{1}{2(\theta_2+\theta_1)}(2\theta_1 + (T_A - T_B + \delta(s_A - s_B))$$

So, first-period profits for providers are $\pi_1^A = \alpha T_A$ and $\pi_1^B = (1-\alpha)T_B$.

Providers maximize their multiperiod profits over first period prices T_i and switching fees s_i :

$$\max_{T_A,s_A} \pi_A(T_A, T_B, s_A, s_B) = \pi_{1A} + \delta\pi^*_{2A}$$
$$\max_{T_B,s_B} \pi_B(T_A, T_B, s_A, s_B) = \pi_{1B} + \delta\pi^*_{2B}$$

I omit the detailed multiperiod profit functions, which are quadratic in their arguments (first-period prices and switching fees).[16] Solving the system of equations, we get an interior solution, subgame perfect equilibria where optimal first period prices are: [17]

$$T_A^* = \frac{2}{3}(\theta_1 + 2\theta_2) - \delta(\frac{\omega}{3} + s_A) \tag{10}$$
$$T_B^* = \frac{2}{3}(2\theta_1 + \theta_2) - \delta(\frac{\omega}{3} + s_B) \tag{11}$$

There are not unique values for the switching fees, but they are bounded according to firms' and consumers' constraints.[18] Since we do not impose exit barriers for firms, and to avoid they leave the market in the second period, we restrict second period profits to be at least zero. Consumers, in other hand, will have at least zero expected second period payoffs. Thus $\forall i \in \{A, B\}$

$$-\frac{\omega(2\theta_1 + 3\theta_2)}{3(\theta_1 + 2\theta_2)} \leq s_A^* \qquad \text{thus, } \pi_{2A} \geq 0 \tag{12}$$
$$-\frac{\omega(3\theta_1 + 2\theta_2)}{3(2\theta_1 + \theta_2)} \leq s_B^* \qquad \text{thus, } \pi_{2B} \geq 0 \tag{13}$$
$$s_i^* \leq v - \frac{11\omega}{18} \qquad \text{thus, } E[R_{2i}] \geq 0 \tag{14}$$

Given the boundaries for switching fees, s^{min} and s^{max}, both are decreasing in the exogenous switching cost parameter ω.[19] An increase of the exogenous switching cost parameter would displace the feasible region for switching fees at a lower level, which would imply a substitudability between exogenous and endogenous switching costs: lower exogenous switching costs imply higher upper bound for switching fees. It is important to highlight that switching fees, s_A and s_B, are not necessarily equal, but

[16] The second derivatives are negative: $\frac{\partial^2\pi^A}{\partial {T_A}^2} = \frac{\partial^2\pi^B}{\partial {T_B}^2} = -\frac{1}{(\theta_1+\theta_2)} < 0$, and $\frac{\partial^2\pi^A}{\partial s_A^2} = \frac{\partial^2\pi^B}{\partial s_B^2} = -\frac{\delta^2}{(\theta_1+\theta_2)} < 0$.

[17] The assumption of having consumers and providers equally patient also guarantees the Hessian matrix of the system of equations to be negative semi-definite, sufficient condition to get an interior solution.

[18] Switching fees cannot be infinite, because otherwise consumers would not buy from the provider that set them. Let's recall that switching fees are set in the first period.

[19] They have negative partial derivatives respect to ω given that $\theta_1 > 0$ and $\theta_2 > 0$.

they must satisfy the above conditions.

Thus, second period prices are given by the following:

$$T_{AA}^{*} = \frac{2\omega}{3} + s_{A}^{*} \tag{15}$$
$$T_{BB}^{*} = \frac{2\omega}{3} + s_{B}^{*} \tag{16}$$

$$T_{BA}^{*} = T_{AB}^{*} = \frac{\omega}{3} \tag{17}$$

First-period prices are decreasing in the exogenous cost parameter ($\frac{\partial T_i^*}{\partial \omega} < 0$) and in the discount factor ($\frac{\partial T_i^*}{\partial \delta} < 0$). Second-period prices are positively affected by exogenous switching cost parameter ($\frac{\partial T_{ii}^*}{\partial \omega} = \frac{2}{3}$ and $\frac{\partial T_{ij}^*}{\partial \omega} = \frac{1}{3}$) and are not affected by the discount factor ($\frac{\partial T_{ii}^*}{\partial \delta} = \frac{\partial T_{ij}^*}{\partial \delta} = 0$). So an external reduction of exogenous switching costs would reduce second period prices, for both loyal consumers and switchers; but this reduction also would increase first period prices and both boundaries of endogenous switching fees (if the change is anticipated for the providers).

First period market share of A, $\alpha = \frac{\theta_1 + 2\theta_2}{3(\theta_1+\theta_2)}$, is increasing in the taste parameter that favors it θ_2, and decreasing in θ_1 (the taste parameter that favors the rival), conversely for the case of market share of provider B. [20] Using (10) to (12) into the profit functions of the providers, second period profits are

$$\pi_{2A}^{*} = \frac{1}{9(\theta_1+\theta_2)}[\omega(2\theta_1 + 3\theta_2) + 3s_A(\theta_1 + 2\theta 2)] \tag{18}$$
$$\pi_{2B}^{*} = \frac{1}{9(\theta_1+\theta_2)}[\omega(3\theta_1 + 2\theta_2) + 3s_B(2\theta_1 + \theta 2)] \tag{19}$$

and multiperiod profits

$$\pi_{A}^{*} = \frac{\delta\omega}{9} + \frac{2(\theta_1 + 2\theta_2)^2}{9(\theta_1+\theta_2)} \tag{20}$$
$$\pi_{B}^{*} = \frac{\delta\omega}{9} + \frac{2(2\theta_1 + \theta_2)^2}{9(\theta_1+\theta_2)} \tag{21}$$

In this interior solution, multiperiod profits are not affected by the presence and setting of switching fees, $\frac{\partial \pi_i^*}{\partial s_i} = 0 \ \forall i \in \{A, B\}$, but profits are increasing in the exogenous switching costs parameter ω and the taste parameter that favors the provider (for instance $\frac{\partial \pi_A^*}{\partial \theta_2} > 0$ and $\frac{\partial \pi_A^*}{\partial \theta_1} < 0$). Given that profits are increasing in ω, it is sensible to think providers would have the incentives to influence in its level. That would explain, why providers would stand against any policy that aims to reduce individual exogenous SC, or even invest in increasing those costs by any means.[21]

[20] It is easy to verify that $\frac{\partial \alpha}{\partial \theta_1} = -\frac{\theta_2}{3(\theta_1+\theta_2)^2} < 0$ and $\frac{\partial \alpha}{\partial \theta_2} = \frac{\theta_1}{3(\theta_1+\theta_2)^2} > 0$.

[21] Creating many complex consumption plans, requiring canceling accounts at certain time in certain location only, using different standards, etc.

The indifferent consumer has an idiosyncratic taste level of $\hat{\sigma} = \frac{\theta_2 - \theta 1}{3}$ and gets multi-period payoff (expected payoff) of

$$R_i = v(1+\delta) - \frac{5\omega\delta}{18} - (\theta_1 + \theta_2) \tag{22}$$

Given the equilibrium outcomes, we get the following total consumer surplus function for consumers of provider A and B are:

$$CS_A = \frac{\theta_1 + 2\theta_2}{54}(18(1+\delta) - 5\delta\omega - 3(5\theta_1 + 4\theta_2))$$
$$CS_B = \frac{2\theta_1 + \theta_2}{54}(18(1+\delta) - 5\delta\omega - 3(4\theta_1 + 5\theta_2))$$

Therefore, the total consumer surplus is given by the equation below, which clearly indicates consumer surplus decreases with the individual exogenous switching costs parameter.

$$CS = (\theta_1 + \theta_2)\left(v(1+\delta) - \frac{5\omega\delta}{18}\right) - \frac{13(\theta_1^2 + \theta_2^2)}{18} - \frac{14\theta_1\theta_2}{9} \tag{23}$$

The results are summarized in the following proposition.

Proposition 2. *If $v \geq \frac{5\omega}{18}\frac{\delta}{1+\delta} + \frac{\theta_1+\theta_2}{1+\delta}$, then there are subgame perfect equilibria in pure strategies and a unique equilibrium outcome. Providers get positive multiperiod profits. Different combinations of optimal prices and switching fees lead to same payoffs' functions. Multiperiod profits and multiperiod payoffs of consumers are unaffected by the use of switching fees.*
First period market share of a provider increases with the taste parameter that favors it, and a third of the population switches in the second period.

The equilibria described in proposition 2, is supported by prices, profits and consumer payoff given by equations (10) to (22).

Increasing the taste parameter, either θ_1 or θ_2 will determine consumers' choice of a provider. Therefore, providers would have the incentive to invest in changing the magnitude of these preferences. The following section extends the model.

3.3 Providers invest on marketing

Given that providers increases market share and profits with relative preference parameter, we enable providers to invest on it. Thus, assuming this 'marketing' cost to be convex, and for any $\phi > 0$, providers' first period profit changes to:

$$\pi_{1A} = \alpha T_A - \phi\theta_2^2$$
$$\pi_{1B} = (1-\alpha)T_B - \phi\theta_1^2$$

In the stage zero of period one, providers decide how much to invest to increase the relative taste that favors them. Thus, the timeline of this extended model is depicted in the following diagram.

$t=1$			$t=2$	
Stage 0	Stage 1	Stage 2	Stage 1	Stage 2
Providers invest on increasing taste preferences towards them, set level (θ_1,θ_2)	Providers set flat prices (T_A,T_B) and switching fees (s_A,s_B)	Consumers learn σ_k, then given prices and preferences they choose their provider	Providers set new flat prices (T_{AA},T_{BA}), (T_{BB},T_{AB})	Consumers learn x_k, then given new prices, they decide to stay or to switch

Second-period results still apply, but first-period results differ from previous analysis due to the introduction of convex costs of advertising. Thus, solving by backward induction, providers' marketing investment lead to equal maximum relative preferences level,

$$\theta_1^* = \theta_2^* = \frac{5}{12\phi} \tag{24}$$

In the equilibria, $\hat{\sigma} = 0$ and providers A and B split the market equally, $\alpha = \frac{1}{2}$. Switching fees are such that $\forall i \in \{A, B\}$

$$-\frac{5\omega}{9} \leq s_i^* \qquad \text{thus, } \pi_{2i} \geq 0 \tag{25}$$

$$s_i^* \leq v - \frac{11\omega}{18} \qquad \text{thus, } E[R_{2i}] \geq 0, R_{ij} \geq 0 \tag{26}$$

equilibrium prices are

$$T_i^* = \begin{cases} \frac{5}{6\phi} - \delta(\frac{\omega}{3} + s_i^*) & \text{if } \phi \geq \frac{15}{18v(1+\delta)-5\delta\omega} \\ v(1+\delta) - \delta(\frac{11\omega}{18} + s_i^*) & \text{otherwise} \end{cases} \tag{27}$$

$$\begin{aligned} T_{ii}^* &= \frac{2}{3}\omega + s_i^* \\ T_{BA}^* = T_{AB}^* &= \frac{\omega}{3} \end{aligned} \tag{28}$$

Given the boundaries s^{min} and s^{max}, an increase of the exogenous switching cost parameter would displace the feasible region for switching fees at a lower level.[22] First period prices T_i^* in (27) are such that they guarantee non-negative first-period payoffs to consumers.

Providers make multiperiod profits [23]

$$\pi_A^* = \pi_B^* = \frac{\delta\omega}{9} + \frac{35}{144\phi} \tag{29}$$

Second and first period profits are

$$\pi_{2i}^* = \frac{5\omega}{18} + \frac{s_i}{2}$$

[22]They have negative partial derivatives respect to ω, $\frac{\partial s_i^{mi}}{\partial\omega} = -\frac{5}{9} < 0$, and $\frac{\partial s_i^{ma}}{\partial\omega} = -\frac{11}{18} < 0$.
[23]The threshold levels to switch in the second period are $x_A^* = x_B^* = \frac{\omega}{3}$.

$$\pi_{1i}^* = \frac{35}{144\phi} - \delta(\frac{s_i}{2} + \frac{\omega}{6}) \qquad \forall i \in \{A, B\}$$

Notice that $\frac{\partial \pi_{1i}^*}{\partial s_i} < 0$, $\frac{\partial \pi_{2i}^*}{\partial s_i} > 0$, and $\frac{\partial \pi_i^*}{\partial s_i} = 0$.

For chosen switching fees that satisfies (25), an increase in them affects positively to second-period profits but negatively to first-period profits. For the multiperiod profit-maximizer firm, the effects cancel out and its multiperiod profits are unaffected on chosen switching fee's levels.

Multiperiod profits are increasing in the exogenous switching costs parameter ω and in the discount factor δ. First period profits are decreasing in exogenous switching costs and second period profits are increasing in them.

On the other hand, for $\phi \geq \frac{15}{18v(1+\delta)-5\delta\omega}$, the indifferent consumer gets multiperiod payoff of

$$R_i = v(1 + \delta) - \frac{5\omega\delta}{18} - \frac{5}{6\phi} \qquad \forall i \in \{A, B\}$$

Notice also that this payoff does not depend on switching fee.

Additionally, second period market shares are $n_{ii} = \frac{1}{3}$, $n_{ij} = \frac{1}{6}$. Thus the probability to stay loyal is $\frac{2}{3}$ and the probability to switch (the share of switchers) is $\frac{1}{3}$. The results of the two-period model are summarized in the following proposition.

Proposition 3. *If* $v \geq \frac{5\omega}{18}\frac{\delta}{1+\delta} + \frac{1}{6\phi(1+\delta)}$, *then there are subgame perfect equilibria in pure strategies where each firm gets a half of the market in the first period, and a third of the population switches in the second period.*

In these multiple equilibria, where different combinations of optimal prices and switching fees reach the same outcome(payoffs), multiperiod profits and multiperiod payoffs of consumers are not affected by the ability to set switching fees.

Negative switching fees – which mean providers care so much on the present and to extract as much consumer surplus as possible, they would even promise to pay consumers if they decide to leave – are possible in this model but up to a limit, s_i^{mi}. The feasible region remain constant across different level of discount factors, and is displaced downwards with bigger exogenous switching cost parameter (ω).

Proposition 4. *The subgame-perfect equilibrium outcome presented in proposition 3 is unique.*

To prove this last proposition, we have to prove that there is no equilibrium where none switches, and there is no equilibrium where everyone switches. The proof is shown in the appendix.

3.4 Providers do not set switching fees or only one provider sets it

In the scenario where the providers do not set switching fees and maximize profits over prices only, providers solve

$$\max_{T_A} \pi_A(T_A, T_B) = \pi_{1A} + \delta\pi^*_{2A}$$
$$\max_{T_B} \pi_B(T_A, T_B) = \pi_{1B} + \delta\pi^*_{2B}$$

The multiperiod payoffs are the same as if they would have set switching fees.

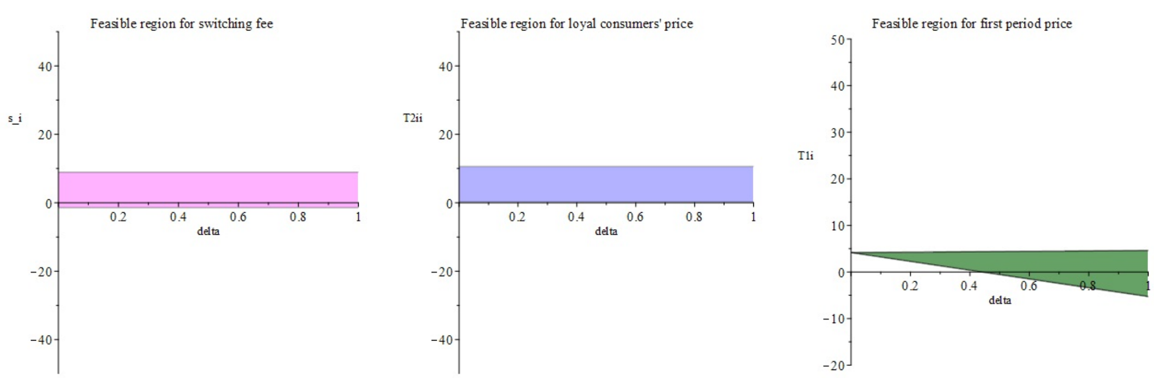
Moreover, if only one provider sets switching fee (and the other do not), such that

$$\max_{T_A, sA} \pi_A(T_A, s_A, T_B) = \pi_{1A} + \delta\pi^*_{2A}$$
$$\max_{T_B} \pi_B(T_A, T_B) = \pi_{1B} + \delta\pi^*_{2B}$$

Then, the obtained payoffs are the same in all scenarios. Switching fees only intensify the intertemporal compensation through prices, and do not affect multiperiod payoffs.

4 Equilibrium analysis: implications

From the symmetric equilibrium conditions given in proposition 3, we can graphically observe the feasible region for switching fees depicted in figure 1. The figures (a) and (b) shows that feasible region for switching fees and price to loyal consumers remain constant across patience level. For first period prices, the upper bound marginally increases with patience level, but the lower bound decreases as the discount factor approaches to one; thus for higher δ, the feasible region of negative prices becomes bigger.

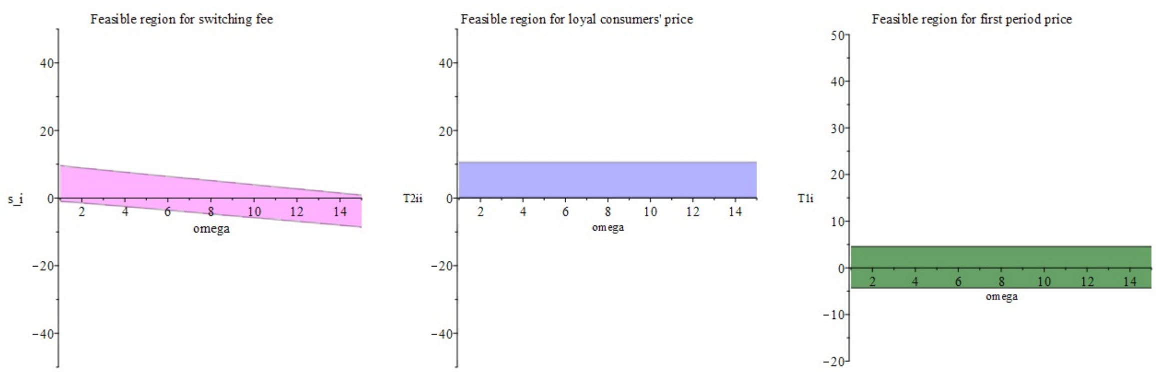


(a) Switching fee s_i (b) Price to loyal consumers T_{ii} (c) First period price T_i

Parameters values: $v = 10$, $\phi = 0.2$ and $\omega = 2$

Figure 1: Feasible regions for switching fees optimal prices as δ changes

In the same fashion, fixing the patience level, we can check that the feasible region for optimal switching fees shifts downwards as the exogenous cost parameter increases – both upper and lower bounds decreases in ω–. Meanwhile, the feasible region for prices to loyal consumer remain constant and above zero, and the first period price remains also constant but it allows for negative prices (see figure 2).

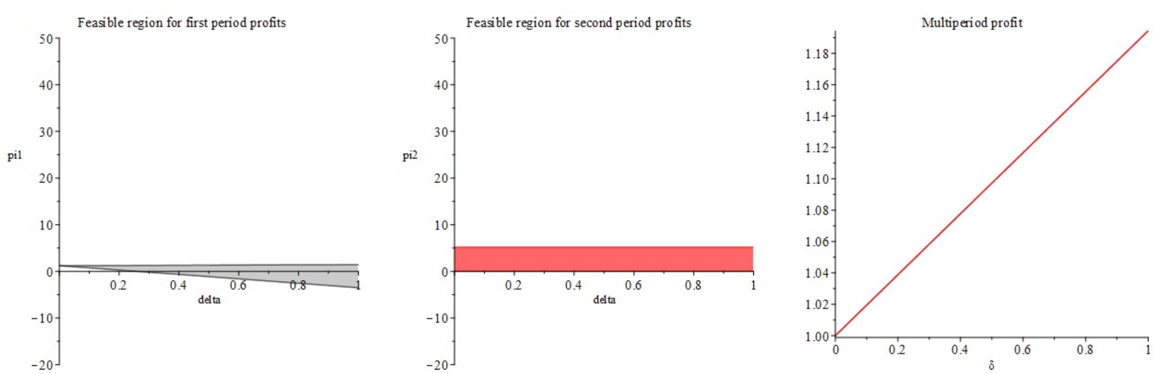


(a) Switching fee s_i (b) Price to loyal consumers T_{ii} (c) First period price T_i

Parameters values: $v = 10$, $\phi = 0.2$ and $\delta = 0.9$

Figure 2: Feasible regions for switching fees optimal prices as ω changes

Although there are many combinations of prices and switching fees, profits are set in a unique way; providers' profits are increasing in the discount rate and the exogenous switching cost parameter. Figure 3 shows the feasible regions for first, second and multiperiod profits. Providers may risk and get negative first period profits as discount factor increases. Despite of the multiplicity of equilibrium outcomes for period-profits due to the use of a range of switching fees, the multiperiod or lifetime profit is uniquely determined.



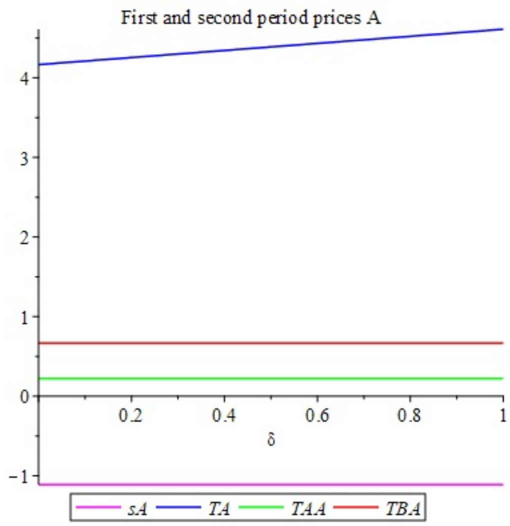
(a) First period profits π_{1i} (b) Second period profits π_{2i} (c) Multiperiod profits π_i

Parameters values: $v = 10$, $\phi = 0.2$ and $\omega = 2$

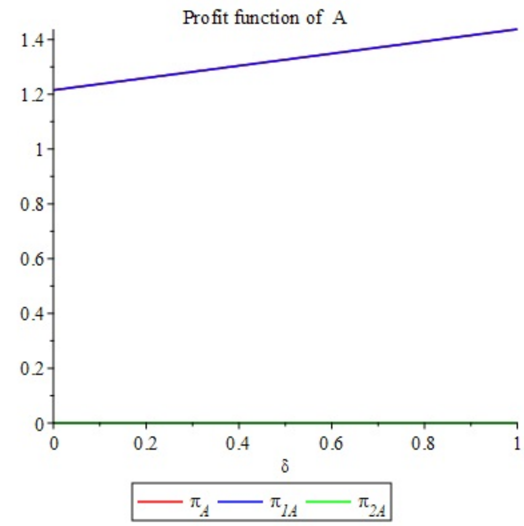
Figure 3: Feasible regions for optimal first period, second period and multiperiod profits across *delta* values

Figures 4 and 5 show the optimal prices and profits as functions of discount factor δ in different scenarios, when providers set minimum and maximum switching fee. Assuming providers always set s^{min}, Figure 4a shows that first-period prices are almost constant and always higher than second-period prices for loyal consumers and switchers; switchers are charged the same regardless of the discount factor.

Likewise, figure 4b depicts the profit functions: multiperiod profit (red line) is always positive and increasing in δ; first-period profits also are positive but they slightly decrease with patience level. Second-period profits are increasing in δ, but they are negative if $s_i = s^{min}$. This result indicates that the effect of a switching fee is intertemporally compensated in providers' profits.



(a) Optimal per period prices



(b) Multiperiod and per period profits

Parameters values: $v = 10$, $\phi = 0.2$ and $\omega = 2$.

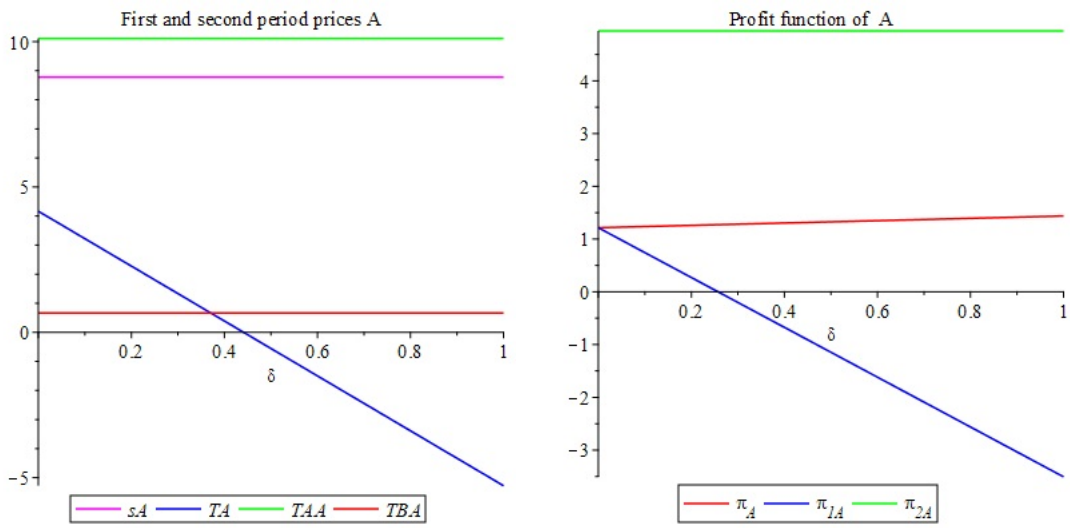
Figure 4: Optimal prices and profits when both providers set $s_i = s^{min}$

When providers set a s^{max}, then second period prices and switching fees are positive, but first period prices quickly becomes negative as discount factor increases. Also first period profit are negative and keep decreasing with patience level, as shown by Figure 5. In this scenario, providers extract the entire consumer surplus in the second period and charge a low (even negative) first-period prices. First period profits also can be negative following the trend of first period prices; despite this, multiperiod profits are kept positive and slightly increasing in δ.

It is important to highlight that the multiperiod profit function in both scenarios is the same, which is explained by the fact that switching fees do not affect multiperiod profits, their effect on period profits are compensated leaving multiperiod profits unaffected.

Figures 6 and 7 show the optimal prices and profits as functions of the switching cost parameter ω when providers set minimum and maximum switching fee (a positive amount).[24] It is always the case that second period prices increases with ω, while switching fees decreases with ω. When switching fees are set at its minimum (a negative

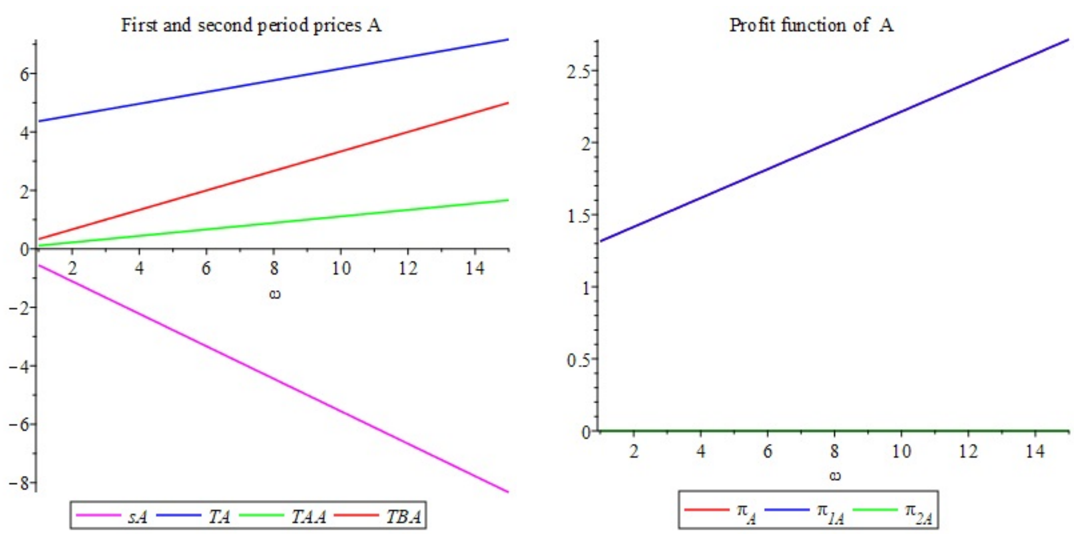
[24]Figures 11 and 12 show the optimal prices and profits as functions of both, δ and ω. In such scenario, first period prices and first period profits are decreasing in patience level and exogenous cost parameter ω. Loyals are charged higher than switchers and both prices increase with ω, and multiperiod and second period profits are also increasing in ω, but the latter increases more rapidly.



(a) Optimal per period prices (b) Multiperiod and per period profits

Parameters values: $v = 10$, $\phi = 0.2$ and $\omega = 2$.

Figure 5: Optimal prices and profits when both providers set $s_i = s^{max}$

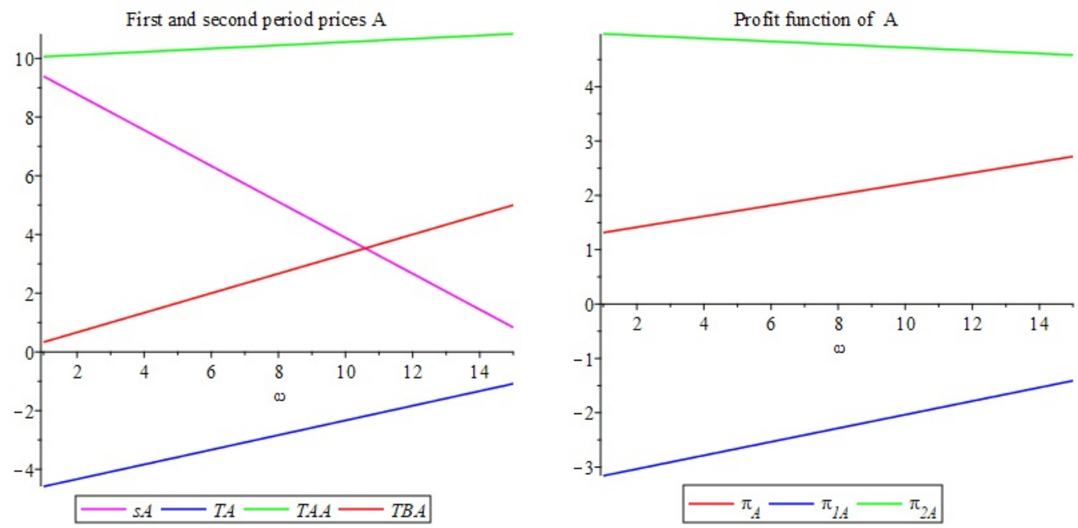


(a) Optimal per period prices (b) Multiperiod and per period profits

Parameters values: $v = 10$, $\phi = 0.2$ and $\delta = 0.9$.

Figure 6: Optimal prices and profits when both providers set $s_i = s^{min}$

amount), first period prices equals the consumer valuation for the service v, and is independent of exogenous switching costs, when switching fee is set at its maximum, first period prices are negative but increasing in ω. Multiperiod profits are always increasing in exogenous switching costs; when minimum switching fees are set, first period profits reach their maximum, while second period profits are negative but increasing in ω. At maximum switching fees, first period profits are negative (to compensate consumers firms set negative first period prices) but increasing in ω; second period prices are pos-



(a) Optimal per period prices

(b) Multiperiod and per period profits

Parameters values: $v = 10$, $\phi = 0.2$ and $\delta = 0.9$.

Figure 7: Optimal prices and profits when both providers set $s_i = s^{max}$

itive but slightly decreasing in ω, this happens due to the effect of lower switching fees collected from more switchers. [25]

Consumer surplus and social welfare

Let's now consider and depict the effect of the equilibrium outcomes, obtained from the extended model, on the consumer surplus and social welfare or total surplus (producer plus consumer surplus). Integrating over consumers, and given $\phi \geq \frac{15}{18v(1+\delta)-5\delta\omega}$,we get the following consumer surplus function:

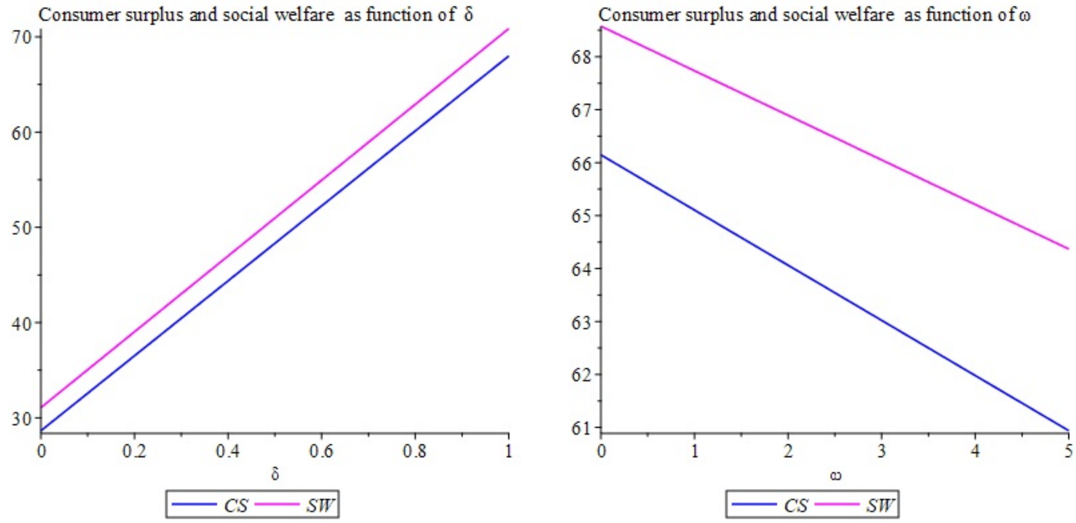
$$CS = \frac{5\delta(18v - 5\omega)}{108\phi} + \frac{5v}{6\phi} - \frac{25}{48\phi^2} \tag{30}$$

Adding the producer surplus generated by the two providers, and under the allowed range for ϕ, we get the following social welfare function:

$$SW = \frac{5\delta(18v - 5\omega)}{108\phi} + \frac{5v}{6\phi} + \frac{2\delta\omega}{9} + \frac{35}{72\phi} - \frac{25}{48\phi^2} \tag{31}$$

Proposition 5. *The presence of switching fees has no affect on consumers' multiperiod payoffs neither providers' multiperiod profits.*
Consumer surplus always decreases with exogenous switching costs ω, and total surplus (social welfare) decreases with ω only for small marketing cost parameter, $\phi \leq 1$.

The ability of providers to set switching fees (endogenous switching costs) do not affect the multiperiod payoff of consumers (they affect per period payoff, and these effects that are canceled out in the total discounted multiperiod payoff), therefore multiperiod consumer surplus is also unaffected by the presence of switching fees. However, consumer's multiperiod and per period payoff are affected by exogenous switching costs.



(a) CS and SW as functions of δ

(b) CS and SW as functions of ω

Parameters values: $\upsilon = 10$, $\phi = 0.2$ and $\omega = 2$.

Figure 8: Consumer surplus and social welfare functions

Given that multiperiod profits of providers are also unaffected by the setting of switching fees, social welfare (defined as the summation of consumer surplus and providers' profits) is also unaffected by switching fees (endogenous switching costs). This result may be striking, but it may explain why in some industries such as telecommunications, switching fees like ETF are being dismissed by some companies. It also agrees with the findings of Cullen et al. (2016) where equilibria where providers with and without switching fees may coexist. In the model presented in this paper that may happen because the effect of switching fees are compensated inter-temporally in such a way that they do not affect payoffs of consumers either providers.

Figures 8a and 8b show the consumer surplus (CS) and social welfare (SW) as functions of the discount factor δ, and of the exogenous switching cost parameter ω whenever $\phi \leq 1$. Both functions are clearly increasing in the patience level (δ), driven basically for greater consumer welfare as patience level increases.

On the other hand, consumer surplus decreases more rapidly with the exogenous switching cost parameter than in the case of social welfare. Thus, less exogenous switching costs would have a greater impact in the short term for consumers.

By using some numerical exercises; Table 1 presents the different calculated values for multiperiod profits (for A and B), multiperiod consumer surpluses, and multiperiod payoff of a typical consumer, as well as per period profits and typical consumer's payoff under different scenarios.

For the same discount factor ($\delta = 0.9$), this table 1 shows that for any combina-

[25] Recall that the switchers' share rises with ω.

	s^{min} vs. s^{max}		A and B set $s_i = 0$	$s_i = 0$ vs. s^{max}		$s_i = 0$ vs. s^{min}	
	A (s^{min})	B (s^{max})	Firm i	A ($s_i = 0$)	B (s^{max})	A ($s_i = 0$)	B (s^{min})
Multiperiod profit π_i	**1.42**	**1.42**	**1.42**	**1.42**	**1.42**	**1.42**	**1.42**
π_{1i}	1.42	-3.03	0.92	0.92	-3.03	0.92	1.42
π_{2i}	0	4.94	0.56	0.56	4.94	0.55	0
T_i	**4.57**	**-4.33**	**3.57**	3.57	**-4.33**	3.57	**4.57**
s_i	-1.11	8.78	0	0	8.78	0	-1.11
T_{ii}	0.22	10.11	**1.33**	1.33	10.11	1.33	0.22
Cost of switching max	1.56	11.44	2.67	2.67	11.44	2.67	1.56
Cost of switching min	-0.44	9.44	0.67	0.67	9.44	0.67	-0.44
R_i	**14.33**	**14.33**	**14.33**	**14.33**	**14.33**	**14.33**	**14.33**
R_{1i}	5.43	**14.33**	**6.43**	6.43	14.33	6.43	5.43
ER_i	**9.89**	**0**	**8.78**	8.78	0	8.78	9.89
$R_{ii} = R_{ij}$	9.78	**-0.11**	8.67	8.67	-0.11	8.67	9.78
CS^i	**32.03**	**32.03**	**32.03**	**32.03**	**32.03**	**32.03**	**32.03**
CS	**64.06**	**64.06**	**64.06**	**64.06**	**64.06**	**64.06**	**64.06**
SW	**66.89**	**66.89**	**66.89**	**66.89**	**66.89**	**66.89**	**66.89**

Parameters values: $\delta = 0.9$, $v = 10$, $\omega = 2$, and $\phi = 0.2$.
Prices to switchers are $T_{2j}^i = 0.67$, and $\theta_1 = \theta_2 = 2.08$ for all the cases.
Cost of switching includes switching fee, maximum (minimum) exogenous switching cost $\omega(0)$ and switcher's price.

Table 1: Providers set different switching fee, s^{min}, $s_i = 0$ or s^{max}

tion of maximum or lowest switching fees used by the providers, multiperiod payoffs (profits, indirect utilities, and consumer surpluses) are kept unchanged. The observed differences come from the existing trade-off between inter-temporal payoffs when a low or high switching fee is chosen by the providers.

4.1 Discussion and policy implications

The model developed in this paper, show that exogenous switching costs are more relevant than endogenous switching costs in the decision making of consumers. For the providers, switching fees would not affect multi-period profits, but would accentuate a trade off between present and future profits. Providers with high switching fees would compensate consumers with lower first period prices, but would charge higher second period prices to loyal consumers; low switching fees would be associated to high first period prices and lower second period prices to loyals. Thus consumers with lower first period surplus get compensated with higher second period surplus, and *vice versa*.

Second period prices are positively affected by exogenous switching cost parameter ω. Therefore an unanticipated external reduction of exogenous switching costs would reduce second period prices, for both loyal consumers and switchers; however, if the change is anticipated for the providers, this reduction also would increase first period prices and possibly leads to higher switching fees.

On the other hand, since profits are increasing in exogenous switching costs ω, providers will have incentives to keep a high ω (opposing to regulatory changes such number portability or standardization or even by increasing searching costs). Also, given that profits are increasing in relative taste parameters, providers have greater incentives to invest in advertising to influence consumer preferences, when they do, in a symmetric case, firms invest until they both get same relative taste level.

According to the model, firms charge higher to loyal consumers than to newcomers in the second period when a maximum switching fee is charged, and otherwise if the minimum switching fee is applied. Furthermore, when s^{max} is used by both providers, then these charge higher to loyal consumers in the second period respect to first period prices.

Once again, switching fees do not play any role in total discounted payoffs (profits and consumer surplus). The negative effect of switching fees on first period profits cancels out with the positive effect it has in the second period profits. This would explain why we observe some competing providers that dismiss switching fees from their pricing strategy, while others maintain it. This result is also consistent with the findings of Cullen et al. (2016).

Hence, policies that target exogenous switching costs reduction may have higher impact on social welfare than those that ban any existence of switching fees (endogenous SC); external reduction of exogenous switching costs increases social welfare, by increasing consumer surplus.

The model suggests that regulatory policies that reduce exogenous switching costs such as number portability (in telecommunication industries, or banking industries), compatibility, standardization, or reduction of administrative barriers, would be more effective in increasing social welfare than policies that reduce endogenous switching costs such as switching fees (ETF in telecommunication industry), because the expected outcomes (payoffs) remain the same despite variations of switching fees.

5 Empirical application: mobile telecommunications industry

In mobile telecommunications industry, switching costs can be showed explicitly as form of exclusive contracts and early termination fees ETF, and also in the form of lack of number portability. Less explicit are the switching costs associated with the paperwork involved in porting phone numbers from one provider to another, and increasing difficulty in comparing among each time many price menus, adding to the search an learning costs.[26] Additionally, it can be argued that network effects added to switching costs may cause stronger consumers' inertia.

As a response, telecommunication regulatory agencies across the world have been implementing number portability policies to reduce switching costs and increase competition. Previous empirical studies show evidence that supports the predicted adverse effects of switching costs in competition. According to Viard (2003) and Lee et al. (2006), number portability policies in countries such as the USA and Korea, respectively, indeed lowered the existing switching costs and led firms to reduce their prices improving competition conditions. Lee et al. (2006) find that 'having to buy a new phone' was the second highest switching barrier for consumers.[27] In what remains of the paper, I show

[26] According to Grzybowski and Liang (2015), European consumers face between 26 and 46 price schedules to choose one in the fixed-mobile bundles. In Peru, by September of 2014, there were around 368 price schedules for the postpaid type of service, 186 and 127 offered, respectively, by Movistar and Claro the largest companies.

[27] Both Viard (2003) and Lee et al. (2006) estimate static models, while the first uses a difference in difference

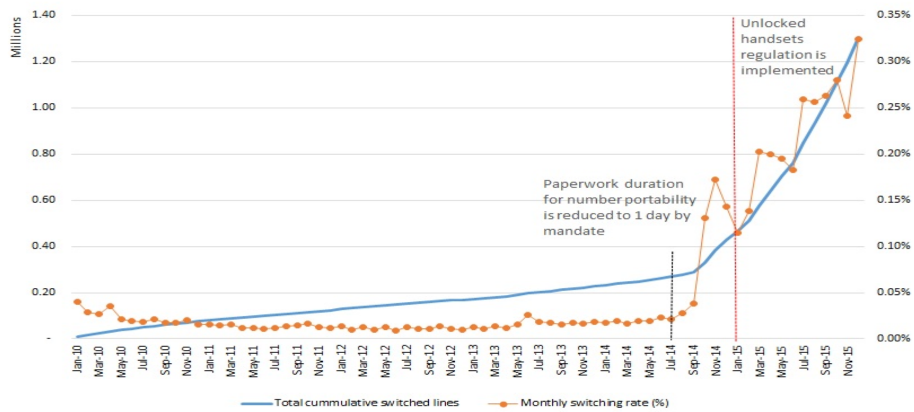


Figure 9: Peru: Switched mobile lines and monthly switching rate (2010-2015)

Source: OSIPTEL- Telecommunications Regulatory Agency

empirical evidence for the Peruvian market.

In Peru, the number portability reform was implemented in 2010 after being announced in 2007.[28] This reform allowed consumers to keep their phone number, restricted the paperwork duration to five business days and reduced forced contract duration.[29] The number of switched lines were minimal; by 2014, in more than three years of the regulation, roughly 269 thousand mobile lines switched operators out of 29 million active lines in Peru. This show a very low performance compared to Chile and Colombia, where the figure was around 2.5 million and 1.3 million in 2.5 and 2 years of implementation of the same regulation, respectively. [30]

In July 2014, OSIPTEL, the telecommunications regulatory agency in Peru, mandated to reduce the paperwork time to port numbers from 5 to 1 business day. In November of the same year, the regulatory agency announced its new policy that would be implemented since January 2015 to reinforce number portability: only unlocked handsets would be commercialized (firms had to unlock existing handsets), firms were banned to offer contracts of forced duration as only option.[31] Only in 2015, around 877 thousand lines switched providers, and around 1 million since the unlocked handset policy was announced. Figure (9) shows the drastic change in the cumulative number of ported subscription lines and the monthly switching rate (monthly ported lines over total subscription lines). There is an increased switching behavior after the reduction of portability paperwork and more striking change after the unlocked handsets' policy.[32]

method, the second uses a random coefficient discrete choice model.

[28]First Number portability reform was announced by Law 28999 in April 2007.

[29]Similar reforms were implemented in Chile and Colombia one or two years earlier, and big impact was expected.

[30]By the end of 2014, the number of subscription lines in Colombia was of 55.3 million (Colombian population is around 48.3 million inhabitants), Chile's was of 26.7 million, and Peru's was 30.3 million.

[31]*Resolucion 166-2003-CD/OSIPTEL* in December 2013 to be implemented in 2014, and *Resolucion de Consejo Directivo 138-2014-CD/OSIPTEL* in November 2014 to be implemented in January 2015.

[32]Peru, Colombia and Chile have similar markets, being Chile (with a population of 17.6 million people) the smallest among these three and the one that has promoted more competition in the market; it also leads

Number portability was allowed since 2010, but it was not until handsets were unlocked and the paperwork reduced to observe significant changes in switching providers.[33] This observation also rise questions about the market features in Peru. The market structure is basically duopolistic: by the end of 2014, two out of four companies concentrated 94% of the market share despite the entrance of the fourth at the end of 2014. The two largest players kept their position, so a year later, in 2015, the share of these two was still above 87%.

In addition, the Peruvian market presents stronger network effects than other mobile communications markets, because firms explicitly discriminate between on-net and off-net calls, moreover, they created a "private-network" within their on network, and price accordingly. Also, calls between mobile networks and fixed-line networks are marginal, therefore the market is basically restricted to mobile-to-mobile communications.

Being subject to a service contract and owning a locked handset prevent switching to another company due to the costs involved. Switchers may need to spend time and money, perhaps on ETF, but also to 'unlock' the handset or to buy another locked phone from the new provider. Currently, ETF is observed in service contracts given by the largest provider, but it is absent from the service contracts of other providers. Such coexistence of zero and positive switching fees in the Peruvian market supports my theoretical predictions about switching fees, all network providers not need to apply switching fees, doing it so would only intensify inter-temporal price compensations.

The recent policy implemented in Peru to reduce exogenous switching costs may have allowed increasing switching behavior. Moreover, the two regulatory changes imposed exogenous shocks on switching costs which makes the analysis of the market attractive. The government allowed for number portability in the telecommunications sector in 2010 to enhance competition by reducing switching costs; however other very relevant switching costs such as the locked handsets and lengthy number portability procedure remained until early 2015, when a new regulation was implemented.

Following my theoretical model, an anticipated reduction of a exogenous switching costs would have led to lower prices and profits, and increased consumer surplus. Based on the assumption of uniformly distributed mass of consumers, my model predicts that switching rates do not depend on exogenous switching cost parameter. This basically because any anticipated change would drive firms to act strategically, using different period prices to inter temporally compensate consumers. Thus, acknowledging a future reduction of exogenous switching costs, firms would increase current prices and later reduce prices to compensate their loyal consumers and become attractive to rival's consumers in the following period. Thus, the empirical analysis shown below focuses

the major regulatory changes in the region. Chile implemented its number portability policy initially in 2010, strengthened it by banning lock-phone sales in 2012, and allowed the entry of MVNOs in 2012. Colombia did the same in the mid of 2011, at the beginning of 2012, and 2013 respectively. It took 5 years to Peru, to implement the second step of number portability policy, and the entry of MVNOs recently was allowed in 2016. The delayed of the second step of number portability policy in Peru may explain the differences in switching behavior.

[33] This is a standard practice around the world, so is the concern about its role in the telecommunications industry, thus the OECD also showed interest to better understand the different mobile handset acquisition models and to analyze the different prices (OECD, 2013).

	Average of monthly Fixed fee	Average per minute price on-net calls	Average per minute price off-net calls	Average per minute price to fixed-line calls	Average per minute price Private Network calls	Average price per SMS	Average price per MMS	Average price per MB of data	Average price per SMS international
Prepaid									
2013	5.80	0.90	1.19	1.08	0.18	0.14	0.41	0.40	0.25
2014	5.80	0.62	0.78	0.73	0.18	0.11	0.36	0.18	0.24
2015	2.25	0.50	0.62	0.60	-	0.10	0.40	0.22	0.23
Postpaid									
2013	74.71	0.69	0.69	0.65	0.27	0.34	0.49	2.70	-
2014	58.99	0.57	0.63	0.63	0.19	0.28	0.56	0.39	0.50
2015	69.46	0.28	0.33	0.34	0.05	0.13	0.34	0.24	0.37

Table 2: Average per unit price (in Peruvian soles - PEN) of popular plans by type of plan

Notes: 1/ Prepaid plans have and average fixed fee because some providers require consumers to purchase prepaid card of minimum value from time to time. Recharge value/prepaid card ranged from 3 to 10 PEN.

Source: OSIPTEL - SIRT, Consumption mobile plans

only on the effect of exogenous switching costs in the demand. Given that the reforms where anticipated (announced and discussed previously in 2014), we should expect service prices in 2015 to fall, and therefore, demand for the service to increase.

5.1 Price behavior

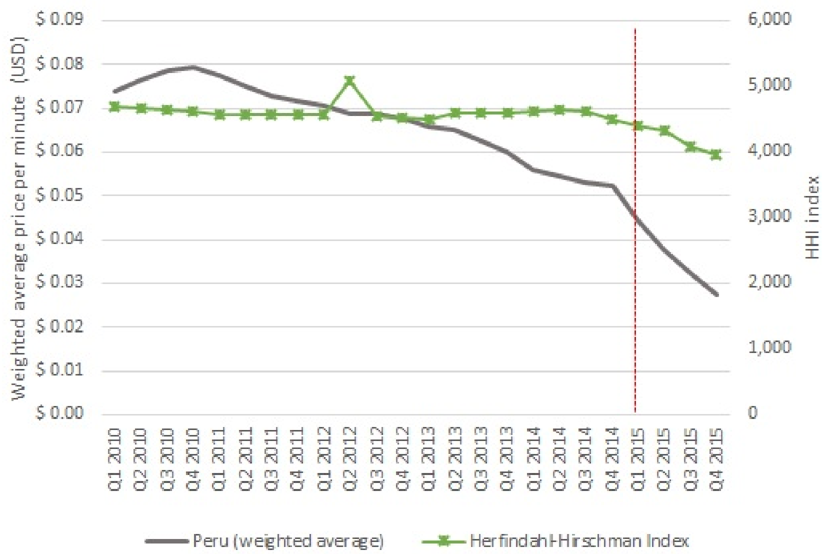
Using the information of around 15 most popular consumption plans for each year, I constructed average prices for each type of call per plan type (postpaid/hybrid and prepaid) per company by the end of each year. [34] The total average per-minute prices per plan type is shown in the table 2.

From the table, we can observe that prepaid consumers face higher per-minute prices than postpaid consumers. Another observation is that per minute prices decreased between 2013 and 2015, and the fall in prices in sharper between 2014 and 2015 in the case of postpaid/hybrid consumers. Let's recall that the main switching cost policy was implemented starting 2015. Likewise, it is worth noting that the average price per MB (data consumption) significantly fell since 2013. This may be explained for an increased smartphone adoption and data demand (that includes access to social networks such as Facebook and Whatsapp), and stronger competition in prices to capture the high-value consumers (postpaid users).

Figure 10 shows the calculated weighted average effective price per minute of mobile

[34] Each consumption plan, may include 10 variations with different fixed fee level, it also includes allowance of minutes off-net, on-net, and private network. They may include allowance for data and SMS as well. However, those varieties of the same consumption plan shared same prices for overage consumption. To find the average price for each type of call and MB of data consumption I averaged overage prices with the implicit paid price within included allowances, dividing the fixed fee by the minutes included, thus I found implicit price per minute (SMS or MB). For cases with unlimited minutes (postpaid and hybrid plans) I considered a maximum number of 50000 minutes, and I restrict my sample of plan variations to those below the fixed fee value of 130 PEN, given that according the ERESTEL, the average postpaid mobile consumer spends 60 PEN per month(the median was 50 PEN) in the service.

call for the country and the market concentration index (HHI). A pronounced decreased in the weighted average price is observed since the last quarter of 2014 and continued during 2015. The unlocked handset policy was announced in November in 2014, but firms would know about the intended change since the end of 2013. It is also noticeable that the slightly decreasing trend of the weighted average per minute price sharpened since the second quarter of 2014 (when the regulation was enacted to be later implemented in January 2015), the weighted average per minute price fell from above USD 0.05 to USD 0.03.



Source: Financial reports and GSMA

Figure 10: Effective price per minute in USD (ARPU/MOU)

A decreasing HHI reflects the increasing role of Entel as the third player; the company left the previous practice of focusing only in a small type of consumers (businessmen and corporations) and expanded its service to prepaid consumers, it also expanded its presence across the country. The impact of Bitel's entry (in the end of 2014) in the market has been small; after a year of operation, it captured 3.5% of the market and competed mostly for prepaid consumers. However, it is relevant to notice that Bitel although it initially attracted consumers, these finally switched to bigger operators, so Bitel did not gained from net ported lines. Until mid 2015 Bitel lost rather than gain ported lines (see figure 13 in the appendix).

In term of voice traffic, the information show a sustain increase in minutes of call, however, since the policy implementation, inbound traffic increase at positive and increasing growth rates, pushing all traffic to grow at positive rates particularly after mid 2015 (see figure 14 in the appendix). Additionally, table 3 shows the increasing average monthly consumption of mobile services between 2013 and 2015 for the surveyed population, which doubled between 2014 and 2015. We also can observe that the minimum consumption level increased by 2015, which suggest an increase in demand for all consumers in the sample.[35].

Year	Max	Mean	Min	Median	N obs.
2013	389.0	31.7	0.0	13.6	2081
2014	623.6	51.5	0.0	32.3	2859
2015	1195.3	102.2	3.0	55.6	2495
Total	1195.3	63.0	0.0	30.6	7435

Notes: Consumption calculated from the reported individual monthly expenditure in mobile services and the average price calculated from price menus of popular plans.

Source: ERESTEL Panel Sample 2013-2015

Table 3: Monthly minutes of call demanded by user (PEN) (2013-2015)

5.2 Empirical evidence

Data

To analyze the effect of the unlocked handsets policy on the market, I gathered information on many sources. The most important source of information is the Peruvian Telecommunications Regulatory Agency (OSIPTEL for its name in Spanish), which supervises the companies and gets detailed firm-level information at monthly or quarterly basis. OSIPTEL has also implemented a national level survey about telecommunication services consumption, which is yearly conducted since 2012 and includes panel data sample since 2013.

I obtained consumer panel-data from the National survey on the demand of telecommunications services and characterization of the users - NSDTSCU [36]. This longitudinal data contains information for the years 2013-2015 of around 1200 households, and 3800 individuals, from which 2800 are mobile phone owners (older than 11 years old). This data set contains information at household and individual level on all the telecommunications services (fixed-line, mobile, internet, public telephone service, and paid-TV) and include demographic information such as age, sex, personal income, household expenditure, working status.

I complemented the consumer level information with firm-level information associated to the number of mobile phone subscriptions by type of service (prepaid or postpaid), by region, per company from the regulatory agency. The data are also available for traffic calls (minutes), dis-aggregated by type of service (prepaid or postpaid), destination, and region, at firm level. Likewise, I got data on number portability, the number of lines switched among providers (inter firm switchers) from January 2010, in a monthly basis. In terms of infrastructure investment, I collected quarterly data on the number of base stations per company per region. Detailed information on characteristics of mobile consumption plans are also published by the regulatory agency. In addition, I

[35]Individual consumption of mobile services are measured as minutes of call per consumer, obtained by dividing the declared monthly expenditure in mobile services and the calculated average price per plan per company

[36]*Encuesta de Demanda de Servicios de Telecomunicaciones y Caracterizacion de los Usuarios -ERESTEL* in Spanish

was provided with the list of the names of the most popular consumption plans (those that jointly get 50% of each company's subscribers) per company per type of service per year for 2013, 2014 and 2015. This information is helpful to focus the gathering of relevant average plan characteristics and price differentials between on-net, off-net and private-network minutes.

In order to check locked and unlocked handsets' prices, I gathered information on handset prices from providers' catalogs and on imported quantity and price of handsets by importer for the period between Jan. 2014 to Dec. 2015 from the Customs Office of Peru (The Tax and Customs Administration Office (SUNAT for its name in Spanish), through their ADUANET service.

Finally I collected quarterly financial information from companies' financial reports provide, mainly on revenues and earnings' margins. From that information, data of the Average Revenue per User (ARPU) for mobile service provision and Average Revenue per Minute (ARPM) of mobile communications are constructed. I have collected quarterly data from 2008 to 2015 of ARPU for the two major companies, and the ARPM for the largest company by type of service (postpaid and prepaid). To complement this information, I also obtained partial information from GSMA intelligence, from which I took data on revenues, performance indicators, calculated effective per-minute prices (average revenue per minute of traffic call) for all operators and a weighted average at national level.

Based on all these sources, I built a longitudinal data set for 5464 individuals during 3 years, from which 1382 are mobile phone consumers along the three years. Table 4 (in the appendix) shows the summary statistics of the main variables of mobile phone users that I use for the model estimation, which is explain in the next subsection. It is important to mention that I constructed the variable minutes consumed per individual (absent in the consumer panel data information) assuming consumers use mobile service only for voice services.[37] Thus, I used the monthly expenditure on mobile services reported by the consumers, and the prices –which I collected from the popular plans (as representative prices for prepaid and postpaid plans) by provider and for each year – to get the monthly quantity of minutes consumed.[38] These average per minute prices I constructed also allow me to calculate the premium of per-minute price of off-net calls over "private-network"-on-net calls.

From the data, a typical Peruvian mobile phone user is an adult of around 38 years old, who works as employee or auto-employee, consumes 63 minutes of call per month, has been engaged in a romantic relationship, lives in the coast of the country, has some secondary level education, and is also an internet user. More than half of the consumer' household member are also mobile users, and uses the mobile services three to more years; and between 3 to 4% of the mobile users own more than one phone number or handset. Around 60% of the mobile users in the data set remain with same consumption plan and the same company, 20% would take advantage of the "on sale" promotions of the network providers, around 22% are observed to switched providers

[37]Peru has a pay-who-calls system, so that the variables minutes consumed refers to minutes each user paid for starting a call. In the aggregate, these minutes comprises the outbound minutes traffic.

[38]I also used the share of on-net and off-net calls per provider to construct a more accurate per provider per plan average per minute price.

between periods.[39] From the firm-level data, the premium of the price of an unlocked handset over a locked one is in average 54%, and the premium of the per-minute price of off-net calls over private-network calls is found to be huge, around 810%.

Methodology and estimation strategy

Aiming to show that a reduction on exogenous switching costs affects market equilibrium outcome, I restrict my analysis to test the hypothesis that such reduction (unlocked handset policy) led to lower average prices, therefore to an increase in the demand for minutes. For the purpose to show some empirical evidence that support my theoretical model, I only perform a reduced form model estimation to find evidence of a negative relationship of exogenous switching costs and the demand for mobile phone services.[40]

I estimate the demand for minutes using the instrumental variables approach. I control for demographic characteristics, and include control variables for switching costs and network effects. To control for endogeneity, I use instruments (supply shifters) for the variable per minute price. The estimated demand equation is presented in the following way, in which the dependent variable is the log of minutes consumed by individual i, from firm j at period t, $ln(q_{ijt})$.

$$ln(q_{ijt}) = \alpha_i + \beta_1 ln(p_{jt}) + \beta_2 (X^1_{it} + X^2_i) + N'\beta_3 + s_t(\beta_4 + \beta_5 * 1\{d_{it}\}) + \beta_6 * Entel + \beta_7 * Bitel + \epsilon_{ijt} \quad (32)$$

In this equation, $ln(p_{jt})$ is the log of the average effective price per minute of call for each company j in year t. [41] To capture the invariant unobserved individual-specific characteristics, I use α_i, which would refer to the idiosyncratic taste shock in the theoretical model, assumed to be totally random here. X^1_{it} and X^2_i denote time variant and time invariant demographic characteristics. These demographic characteristics include age, sex (female=1), ever mate dummy variable (1 if ever mate), maximum level of education, geographic area of residence (coast, highlands and amazon forest), log of monthly household income per household member, mobile service tenure (1=less than a year, 2= 1∼2 years, 3= 2∼3 years, 4= more than 3 years), working status (1=working), type of worker (1=employer, 4=unpaid worker), dummy variable for who pays for the mobile service (1=herself), dummy variable for owning more than one handset and another for owning many phone numbers, dummy variables for having taken promotions/sales, for having internet service at home and for being an internet user.

To control for the network effects, the vector N includes the log of share mobile users within each household, the lagged market share of each company in each region of Peru (there are 24 regions), and the variable pr_{jt} that shows the premium of average per-minute price of off-net minutes over average per-minute price of on-net-private-network minutes. Likewise, to control for the effect of the expansion policy of Entel(Nextel) and the entry of the fourth company (Bitel) to the market, I use a dummy variables *Entel*

[39] This variable equal one when the reported provider of the consumer in the period t is different from the one in $t-1$.

[40] In an ongoing research I am working on better methods that can exploit the information I have collected. It is fair to mention that those results are going to be part of a different paper.

[41] This variable is calculated as the quotient of total revenues per firm and total traffic of minutes (outbound and inbound traffic).

and *Bitel*.

To capture the effect of the reduction of switching costs (unlocked handset policy), I use variable the average premium of the price for getting an unlocked handset over a locked one s_t; this term enters to the equation directly and through an interaction with d_{it}, which equals one if a change of providers is observed between years.[42] Additionally, I add a variable *inertia*, which equals one if the consumer kept her same plan and provider from previous period.

To control for endogeneity in the demand equation, I instrument price variable using information I got from the companies, specifically the lagged share of installed base stations in each region, the total subscription lines per company and the lagged log of the share of ported-out lines per company.

Results

Following the IV method with random effects on panel data, I estimated the equation (32); the results are shown in Table 5 (in the appendix). The table also reports estimated coefficients of the fixed effect and first difference models to show robustness of the estimates. Although the model specification relies on random effects, according to the Hausman test I reject the null hypothesis that such random effects model provides consistent estimates. Thus, I use the fixed effects coefficients for the analysis.

As expected, the results give a negative and significant relationship between per-minute price and voice traffic (minutes consumed), moreover the coefficient indicates that the demand for voice-mobile services is price elastic and the price demand elasticity is -4.9. A negative effect of consumer inertia on demand is also found highly significant, in fact the estimate indicates that any change of the current state (consumption plan or company) would increase the demand for minutes by 28%.[43]

Moreover, as predicted by the model, the results give evidence of a negative effect of exogenous switching costs in demand –this, according to my theory, would be related to the positive relation between prices and exogenous switching costs–. Specifically, the indicator of the exogenous switching costs (the unlocked handset premium combined with switching behavior) shows a statistically significant negative coefficient implying that the policy (a reduction of the exogenous switching costs associated to the extra costs of owning an unlocked handset) would have generated an increase of 33% of the demand for minutes for switchers. Furthermore, the estimated significant coefficient of the effect of the handset policy (the unlocked handset price premium) in the random effects model suggest that all consumers benefited from the handset policy reform.[44]

From the variables used to control for network effects, only the premium of the per-minute price off-net over private-network calls is found to be significant at the 5%.

[42] The information on premium of unlocked handsets was gathered taking into account price catalogs of companies (such as Claro) and the premium calculated by OSIPTEL for the years 2013 and 2014, from 2015 on this premium was just zero.

[43] The calculation comes from $100 * (e^{-0.33} - 1)$.

[44] According to the specification test, random effects estimates are not consistent, but a naive interpretation of such results would indicate that the policy would have caused an increase of 58% in the demand for minutes (mobile services).

The estimation shows that network effects coming from this off-net and on-net price discrimination negatively impact the demand for minutes. This may happen due to a reduction of market concentration of network providers, which implies consumers may require making more off-net calls to communicate with others but facing higher per-minute prices.

Among other significant variables, I find that the demand for minutes increase with income, age, the share of mobile users within the consumer's household, internet usage and availability of it at home, and increased with the expansion of Entel(Nextel) and the entry of Bitel. Single people would also demand more mobile minutes, and demand for minutes decreases with mobile service tenure.

6 Conclusions

The model developed in this paper shows that exogenous switching costs are more relevant than endogenous switching costs in the decision making of consumers. For the providers, switching fees would not affect multiperiod profits but would accentuate a trade-off between present and future profits. Providers with high switching fees would compensate consumers with lower first period prices, but would charge higher second-period prices to loyal consumers; low switching fees would be associated with high first-period prices and lower second-period prices to loyals. Thus consumers with lower first-period surplus get compensated with a higher second-period surplus and vice versa.

Second-period prices are positively affected by exogenous switching cost parameter ω. Therefore an unanticipated external reduction of exogenous switching costs would reduce second-period prices, for both loyal consumers and switchers; however, if the providers anticipate the change, this reduction also would increase first-period prices and the possibility of higher switching fees. However, since the adverse effect of switching fees on first-period profits cancels out with their positive effect on the second-period profits, then regulatory policies should focus more on policy measures that reduce exogenous switching costs such as standardization, compatibility, number portability, red-tape reduction, etc.

On the other hand, since multiperiod profits are increasing in exogenous switching costs ω, therefore providers will have incentives to keep a high ω (opposing to regulatory changes such number portability or standardization or even by increasing searching costs). However, high exogenous switching costs induce firms to price very low or even negative in the first period to attract consumers, despite of charging a maximum switching fee; first period profits are decreasing in exogenous switching costs.

According to the model, providers charge higher to loyal consumers than to newcomers in the second period when patience level is high. When both providers charge a maximum switching fee, then they charge higher to loyal consumers in the second period respect to first-period prices.

The effect of switching fees in multiperiod payoffs is null, in other words, switching fees are neutral. Hence policies that target exogenous switching costs reduction may have a higher impact on social welfare than those that ban any existence of switching fees (endogenous SC); external reduction of exogenous switching costs increases social welfare, by increasing consumer surplus.

Regarding this last prediction and using microdata for the mobile telecomunications industry in Peru, I present some empirical evidence that supports some of my theoretical predictions. In fact, after controlling for network effects and market entry, I found reduced-form evidence of the negative and statistically significant impact of exogenous switching costs on consumers' demand for mobile phone service (minutes of call), which in terms of my theoretical models suggests a negative relationship between exogenous switching costs and second period prices.

The results from the demand estimation indicates that the unlocked handset policy reform –an external reduction of exogenous switching costs– implemented in Peru in 2015 would have induced an increase of demand of minutes of 33% particularly for those that switched providers. Furthermore, given that 61% of the consumers do not change their choice status (plan type and company), the estimation suggests that any change in consumers' *status quo* would increase the demand for mobile services by 28%.

References

Aghion, P. and P. Bolton (1987). Contracts as a barrier to entry. *The American Economic Review 77*(3), 388–401.

Anderson, S., A. Palma, and J. Thisse (1992). *Discrete choice theory of product differentiation*. The MIT Press.

Arie, G. and P. Grieco (2014, 419). Who pays for switching costs? *Quantitative Marketing and Economics* (12), 379.

Beggs, A. and P. Klemperer (1992). Multi-period competition with switching costs. *Econometrica 60*, 651–666.

Biglaiser, G., J. Cremer, and G. Dobos (2013). The value of switching costs. *Journal of Economic Theory 148*, 935–952.

Biglaiser, G., J. Cremer, and G. Dobos (2016). Heterogenous switching costs. *International Journal of Industrial Organization 47*, 62–87.

Cabral, L. (2012, April). Switching costs and equilibrium prices. New York University.

Cabral, L. (2016, April). Dynamic pricing in customer markets with switching costs. *Review of Economic Dynamics 20*, 43–62.

Caminal, R. and C. Matutes (1990). Endogenous switching costs in a duopoly model. *International Journal of Industrial Organization 8*, 353–373.

Chen, Y. (1997). Paying customers to switch. *Journal of Economics and Management Strategy 6*, 877–897.

Cullen, J., N. Schutz, and O. Shcherbakov (2016, April). Welfare analysis of equilibria with and witwith early termination fees in the u.s. wireless industry. International Industrial Organization Conference 2016.

Dube, J., G. Hitsch, and P. Rossi (2009, August). Do switching costs make markets less competitive? *Journal of Marketing Research XLVI*, 435–445.

Fabra, N. and A. Garcia (2015). Dynamic price competition with switching costs. *Dynamic Games and Applications 5*(4), 540–567.

Farrel, J. (1986). A note on inertia in market share. *Economic Letters 21*, 73–75.

Farrel, J. and C. Shapiro (1988). Dynamic competition with switching costs. *RAND Journal of Economics 19*, 123–137.

Fudenberg, D. and J. Tirole (2000). Customer poaching and brand switching. *RAND Journal of Economics 31*, 634–657.

Grzybowski, L. and J. Liang (2015, April). Estimating demand for fixed-mobile bundles and switching costs between tariffs.

Klemperer, P. (1983). Consumer switching costs and price wars. Working Paper. Stanford Graduate School of Business.

Klemperer, P. (1987a, September). The competitiveness of markets with switching costs. *The RAND Journal of Economics 18*(1), 138'150.

Klemperer, P. (1987b). Markets with consumer switching costs. *Quarterly Journal of Economics 102*, 375–394.

Klemperer, P. (1988). Welfare effects of entry into markets with switching costs. *Journal of Industrial Economics 37*, 159–165.

Lee, J., Y. Kim, J. Lee, and Y. Park (2006). Estimating the extend of potential competition in the korean mobile telecommunications market: Switching costs and number portability. *International Journal of Industrial Organization 24*, 107–124.

NERA (2003). Switching costs: Economic models and policy implications. Technical report, Office of Fair Trading and Department of Trade and Industry.

OECD (2013). Mobile handset acquisition models. Technical Report 224, OECD Digital Economy Papers.

Padilla, A. (1995). Revisiting dynamic duopoly competition with consumer switching costs. *Journal of Economic Theory 67*, 520–530.

Pearcy, J. (2011, January). Bargains followed by bargains: When switching costs make markets more competitive.

Shaffer, G. and Z. Zhang (2000). Pay to switch or pay to stay: preference-based price discrimination in markets with switching costs. *Journal of Economics & Management Strategy 9*(3), 397–424.

Shapiro, C. (1999). Exclusivity in network industries. *George Mason Law Review Spring*.

Shi, M. (2013). A theoretical analysis of endogenous and exogenous switching costs. *Quantitative Marketing and Economics* (11), 205–230.

Taylor, C. (2003). Supplier surfing: Competition and consumer behavior in subscription markets. *The RAND Journal in Economics 34*(2), 223–246.

To, T. (1996). Multiperiod competition with switching costs: an overlapping generations formulation. *Journal of Industrial Economics 44*, 81–87.

Toolsema, L. (2009). Interfirm and intrafirm switching costs in a vertical differentiation setting: Green versus nongreen products. *Journal of Economics and M 18*(1), 263–284.

Viard, V. (2003, July). Do switching costs make markets more or less competitive?: The case of 800-number portability. Research paper 1773 - Standford Graduate School of Business.

Wang, R. and Q. Wen (1998, Winter). Strategic invasion in markets with switching costs. *Journal of Economics & Management Strategy 7*(4), 521–549.

Appendix

Proof Proposition 1:
No firm will profitable deviate from the equilibrium prices.

Proof. Suppose provider A deviates and use prices $\widehat{T_{AA}}$ and T^*_{BA} , where $\widehat{T_{AA}} = T^*_{AA}+\Delta$, while provider B keep using equilibrium prices T^*_{BB} and T^*_{AB}. We can check, using (8) that new profits of provider A after deviation are

$$\begin{aligned}
\widehat{\pi_{2A}} &= \alpha\widehat{T_{AA}} - \frac{\alpha}{\omega}(\widehat{T_{AA}} - T^*_{AB} - s^*_A)(\widehat{T_{AA}} - s^*_A) + \frac{(1-\alpha)}{\omega}T^*_{BA}(T^*_{BB} - T^*_{BA} - s^*_B) \\
&= \pi^*_{2A} + \frac{\alpha}{\omega}[\Delta\omega - \Delta(T^*_{AA} - T^*_{AB} - s^*_A) + \Delta(T^*_{AA} - s^*_A) - \Delta^2] \\
&= \pi^*_{2A} - \frac{\alpha\Delta^2}{\omega}
\end{aligned}$$

Then, $\widehat{\pi_{2A}} < \pi^*_{2A}$.

Now, *ceteris paribus*, suppose A deviates to $\widehat{T_{BA}} = T^*_{BA} + \Delta$; then in similar fashion and using (8) that new profits are

$$\begin{aligned}
\widehat{\pi_{2A}} &= \alpha T^*_{AA} - \frac{\alpha}{\omega}(T^*_{AA} - T^*_{AB} - s^*_A)(T^*_{AA} - s^*_A) + \frac{(1-\alpha)}{\omega}\widehat{T_{BA}}(T^*_{BB} - \widehat{T_{BA}} - s^*_B) \\
&= \pi^*_{2A} + \frac{1-\alpha}{\omega}[-\Delta T^*_{BA} + \Delta(T^*_{BB} - T^*_{BA} - s^*_B) - \Delta^2] \\
&= \pi^*_{2A} - \frac{\alpha\Delta^2}{\omega}
\end{aligned}$$

Once again, $\widehat{\pi_{2A}} < \pi^*_{2A}$.

Therefore, regardless of the deviation ($\Delta > 0$ or $\Delta < 0$), profits are always lower than the profit achieved with equilibrium prices, and providers do not have any profitable deviation. □

Expected second period consumer surplus
In the first period, consumers make a choice between providers, therefore, the payoff of a consumer k will be given by :

$$\begin{aligned}
R^A_{1k} &= v + \sigma_k - T_A \\
R^B_{1k} &= v + \sigma_k - T_B
\end{aligned}$$

where σ_k is the relative preference for firm A respect to firm B , and is uniformly distributed on the interval $[-\theta_1, \theta_2]$.

However in the first period, consumers do not take decisions only based on their current period payoffs, but based on their multiperiod payoffs. Thus, each consumer compare R^A vs. R^B

$$\begin{aligned}
R^A &= R^A_1 + \beta E_x[R_{2A}] \\
R^B &= R^B_1 + \beta E_x[R_{2A}]
\end{aligned}$$

where

$$E[R_{2i}] = P_{ii}R_{ii} + P_{ij}R_{ij} \qquad \forall i,j \in \{A,B\}$$

Therefore, we get $E_x[R_{2A}]$ and $E_x[R_{2B}]$ using the distribution of exogenous switching costs x_k

$$E_x[R_{2A}] = v - \left(\int_{x_A}^{\omega} T^*_{AA}\frac{1}{\omega}dx + \int_0^{x_A}(T^*_{AB} + s_A + x)\frac{1}{\omega}dx\right) = v - \tfrac{11}{18}\omega - s_A$$

$$E[R_{2B}] = v - \left(\int_{x_B}^{\omega} T^*_{BB}\frac{1}{\omega}dx + \int_0^{x_B}(T^*_{BA} + s_B + x)\frac{1}{\omega}dx\right) = v - \tfrac{11}{18}\omega - s_B$$

Therefore,

$$\begin{aligned} R_A &= v + \sigma - T_A + \beta(v - \tfrac{11}{18}\omega - s_A) \\ R_B &= v - \sigma - T_B + \beta(v - \tfrac{11}{18}\omega - s_B) \end{aligned}$$

Proof Proposition 4

Claim 1: There is no equilibrium where nobody switches.

Proof. Let's suppose $x_A > \omega \ \ \& \ \ x_B > \omega$ and analyze the game in the second period. In this case, consumers prefer to stay with their provider, which means that the payoffs of a consumer that chose A in the first period are as follows:

$$\begin{aligned} R_{AA} \geq 0 &\ \ \Rightarrow\ \ v \geq T_{AA} \\ R_{AB} \leq 0 &\ \ \Rightarrow\ \ v - s_A - x \leq T_{AB} \end{aligned}$$

Likewise, the payoff of a consumer that chose B in the first period are

$$\begin{aligned} R_{BB} \geq 0 &\ \ \Rightarrow\ \ v \geq T_{BB} \\ R_{BA} \leq 0 &\ \ \Rightarrow\ \ v - s_B - x \leq T_{BA} \end{aligned}$$

Since consumers are better off staying than switching, then $R_{AA} \geq R_{AB}$ and $R_{BB} \geq R_{BA}$. Therefore the following must hold:

$$\begin{aligned} T_{AB} + s_A + x \geq T_{AA} \\ T_{BA} + s_B + x \geq T_{BB} \end{aligned}$$

Given consumers preferences, providers set their second period prices that maximize their profits assuming the rival provider charges zero to newcomers; thus $T_{ii} > 0$ to loyal consumers and $T_{ji} = 0$ for $i \neq j \ \ i,j \in \{A,B\}$ to rival's consumers. Therefore, firm A solves the following problem:

$$\max_{T_{AA}} \pi_{2A} = \alpha T_{AA}$$

$$s.t. \quad \substack{R_{AA} \geq 0 \\ R_{AA} \geq R_{AB} \\ T_{BA} = 0 \\ x \sim U[0,\omega]}$$

which is reduced to the following:

$$\max_{T_{AA}} \pi_{2A} = \alpha T_{AA}$$
$$s.t. \quad T_{AA} \leq min\{v, s_A + x^{min}\}$$

Given the distribution of x, then $x^{min} = 0$. Also, v is the reservation value of any consumer. By construction, $v \leq s_A + x$, therefore, s_A cannot be lower than v. Thus, since profits are increasing in T_{AA}, providers will price as high as possible, which means the maximizing price T_{AA} for firm A is v.

$$T^*_{AA} = v$$

Similarly for firm B, then

$$T^*_{BB} = v$$

Therefore, providers' profits in the second period are given by:

$$\pi^*_{2A} = \alpha v$$
$$\pi^*_{2B} = (1-\alpha)v$$

Now, suppose firm A, *ceteris paribus*, increase its price T^*_{AA} to $\widehat{T_{AA}} = v + \epsilon \quad \forall \epsilon \in (0, \frac{\omega}{2})$. Since it is increasing its price a bit (by ϵ), there will be some consumers that switch. We can check that by looking at the preferences and payoffs of consumers. At the new price $\widehat{T_{AA}}$, consumers will stay when $R_{AA} \geq R_{AB}$, i.e.

$$v - (v + \epsilon) \geq v - 0 - v - x$$
$$x \geq \epsilon$$

thus, provided that $x \in [0, \omega]$, the new choice probabilities are:

$$\widehat{P_{AA}} = \int_{\epsilon}^{\omega} \frac{1}{\omega} dx = \frac{\omega - \epsilon}{\omega}$$
$$\widehat{P_{AB}} = \int_{0}^{\epsilon} \frac{1}{\omega} dx = \frac{\epsilon}{\omega}$$

And the shares of loyal consumers to A and switchers from A to B are $n_{AA} = \alpha\widehat{P_{AA}}$ and $n_{AB} = \alpha\widehat{P_{AB}}$, respectively. Then, new profits become:

$$\begin{aligned}
\widehat{\pi_2^A} &= \alpha(1 - \frac{\epsilon}{\omega})(v + \epsilon) + \alpha\frac{\epsilon}{\omega}v \\
&= \alpha v + \frac{\alpha\epsilon}{\omega}(\omega - \epsilon) \\
&= \pi_2^{A*} + \frac{\alpha\epsilon}{\omega}(\omega - \epsilon)
\end{aligned}$$

Thus, since $\epsilon < \omega$ by construction, firm A would deviate to $\widehat{T_{AA}}$, increasing its price and getting higher profits ($\widehat{\pi_2^A} > \pi_2^{A*}$). Therefore, there is no an equilibrium where nobody switches. $\square$

<u>*Claim 2*</u>: There is no equilibrium where everyone switches.

Proof. Let's suppose $x_A < 0 \;\; \& \;\; x_B < 0$ and as before, I analyze the game in the second period. In this case, consumers prefer to switch rather than stay with their provider, which means that the payoff of a consumer that chose A in the first period are as follows:

$$\begin{aligned} R_{AA} \leq 0 \;\; &\Rightarrow \;\; v \leq T_{AA} \\ R_{AB} \geq 0 \;\; &\Rightarrow \;\; v - s_A - x \geq T_{AB} \end{aligned}$$

Likewise, the payoff of a consumer that chose B in the first period are

$$\begin{aligned} R_{BB} \leq 0 \;\; &\Rightarrow \;\; v \leq T_{BB} \\ R_{BA} \geq 0 \;\; &\Rightarrow \;\; v - s_B - x \geq T_{BA} \end{aligned}$$

Since consumers are better off switching than staying, then $R_{AA} \leq R_{AB}$ and $R_{BB} \leq R_{BA}$. Therefore the following must hold:

$$\begin{aligned} T_{AA} - s_A - x \geq T_{AB} \\ T_{BB} - s_B - x \geq T_{BA} \end{aligned}$$

Given the preferences of consumers, providers set their second period prices that maximize their profits assuming the rival provider charges zero to their consumers in order to retain them; thus $T_{ii} = 0 \; \forall i \in \{A, B\}$.

Therefore, firm A solves the following problem:

$$\max_{T_{BA}} \pi_{2A} = (1-\alpha)T_{BA} + \alpha s_A$$
$$s.t. \;\; \substack{R_{BA} \geq 0 \\ R_{BB} \leq R_{BA} \\ T_{BB} = 0 \\ x \sim U[0,\omega]}$$

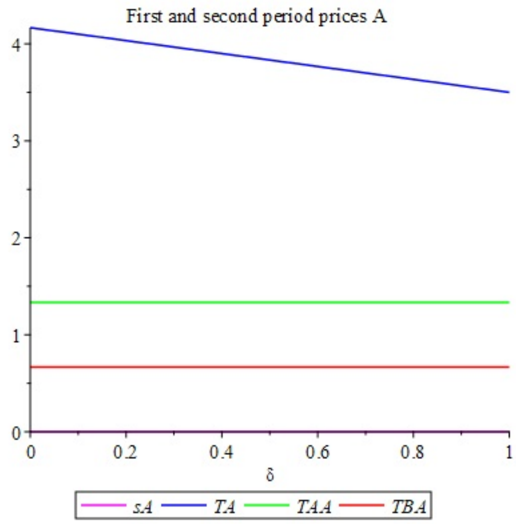
which is reduced to the following:

$$\max_{T_{BA}} \pi_{2A} = (1-\alpha)T_{BA} + \alpha s_A$$
$$s.t. \quad {\scriptstyle T_{BA} \leq min\{v - s_B - x^{max}, -s_B - x^{max}\}}$$

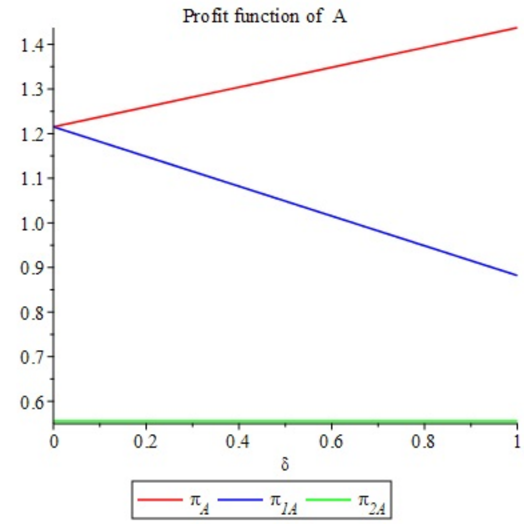
Given the distribution of x, then $x^{max} = \omega$. Recall that provider A charges $T_{AA} = 0$, which imply zero reservation value of consumers for the service, $v = 0$ because this value cannot be negative. Therefore, $T_{BA} = -s_B - \omega$, providers would make losses in the second period. Also, since reservation value of consumers does not change between periods, consumers would not be interested in buying the service if the first period prices are positive, recall that $v = 0$. Thus, providers would need to price zero in both periods, and finally they would just make losses by operating under this case, therefore providers would be better off by not operating. Hence, there is not an equilibrium where everyone switches. $\square$

Given that we claim 1 and 2 are true, we proved proposition 4.

Optimal prices and profit functions when providers set $s_i = 0$



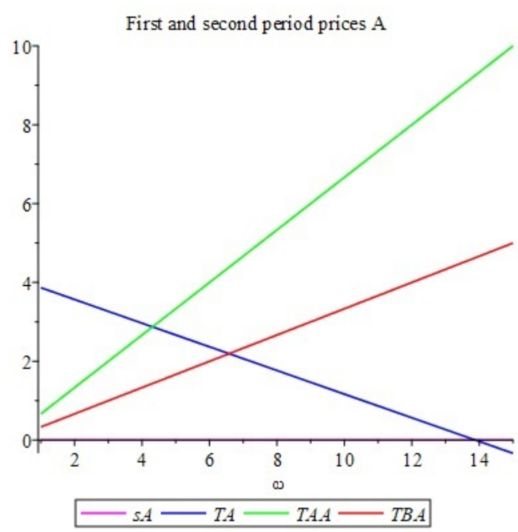
(a) Optimal per period prices



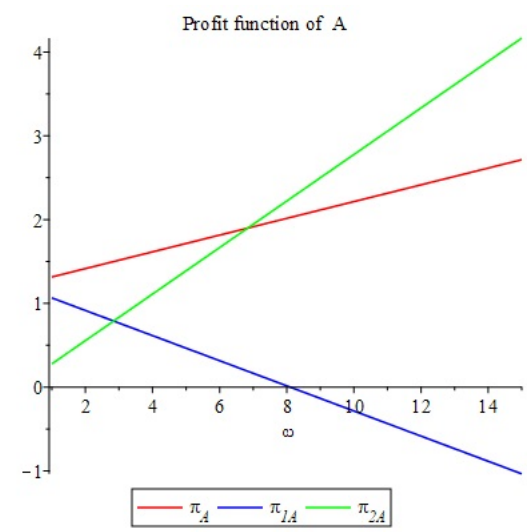
(b) Multiperiod and per period profits

Parameters values: $v = 10$, $\omega = 2$, and $\phi = 0.2$.

Figure 11: Optimal prices and profits as functions of δ, when both providers set $s_i = 0$



(a) Optimal per period prices



(b) Multiperiod and per period profits

Parameters values: $v = 10$, $\omega = 2$, and $\phi = 0.2$.

Figure 12: Optimal prices and profits as functions of ω, when both providers set $s_i = 0$

Empirical application: additional figures

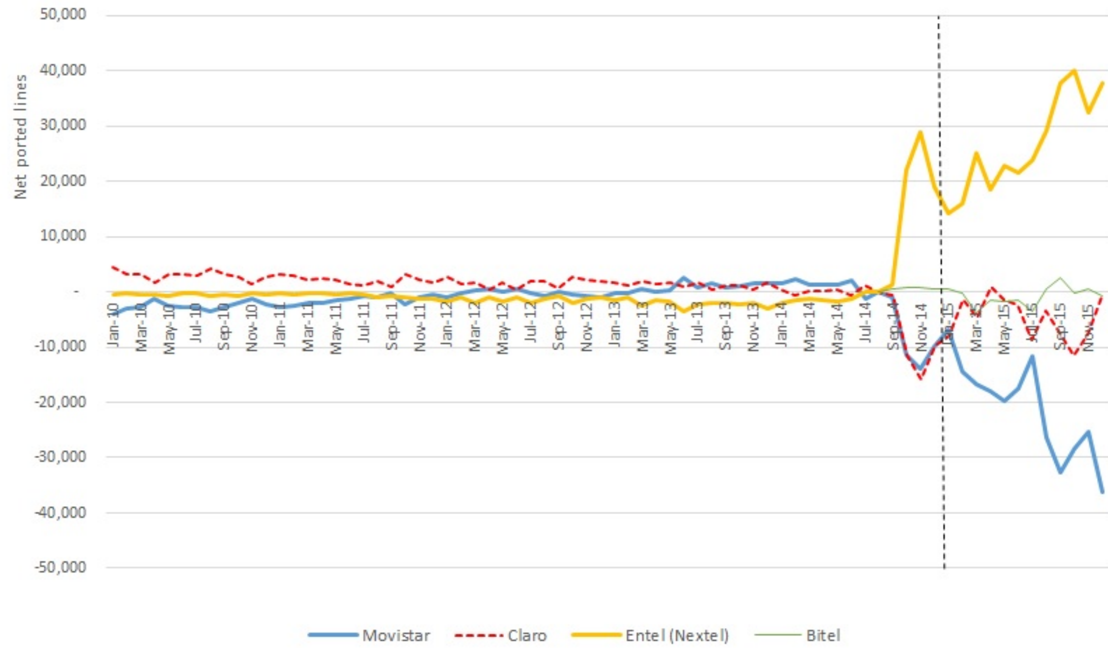
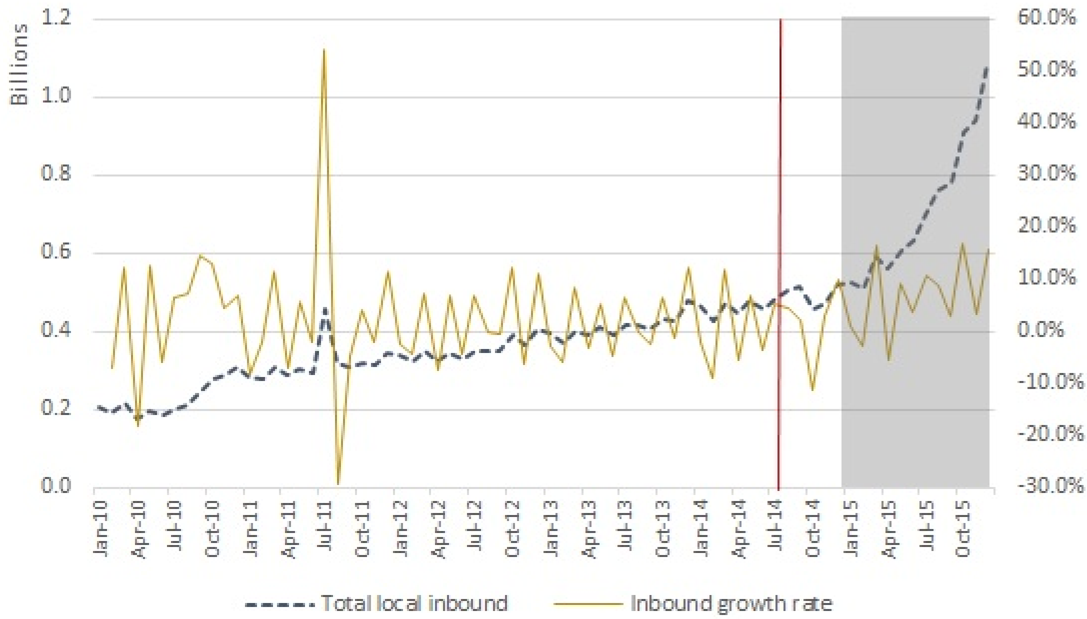
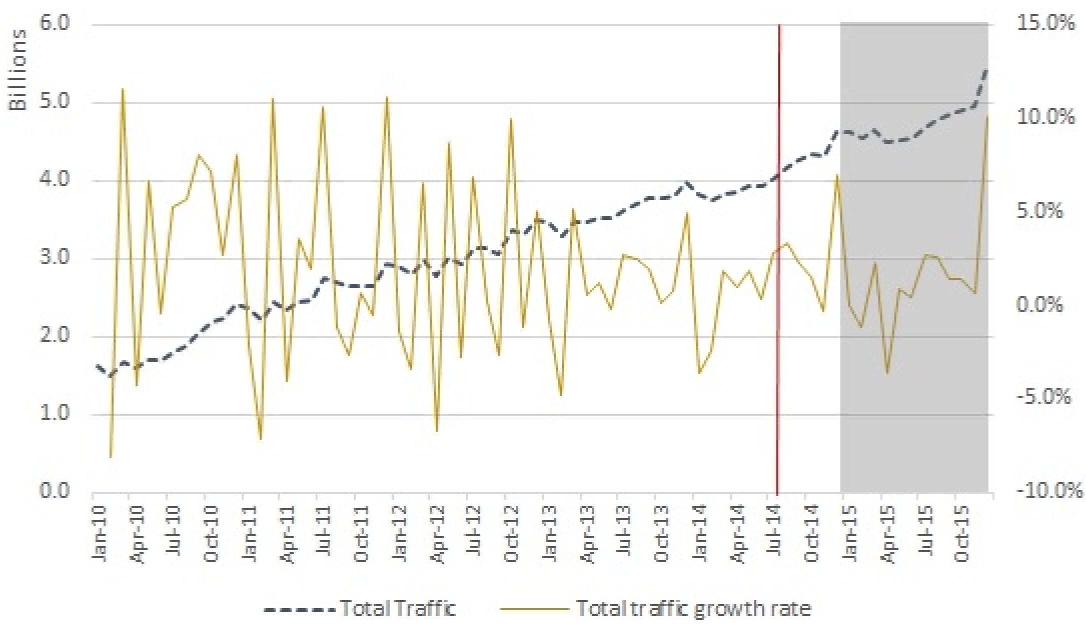


Figure 13: Net ported lines by company per month (Jan 2010 - Dec 2015)

Source: OSIPTEL



(a) Inbound voice traffic (minutes) and growth rate (%)



(b) Total voice traffic (minutes) and growth rate (%)

Figure 14: Voice traffic level and monthly growth rates (Jan 2010 - Dec 2015
Source: OSIPTEL

Table 4: Summary statistics for mobile users

Variable	Mean	Std. Dev.	N
Individual information			
Minutes consumed per month	62.962	92.353	7435
Inertia ($1\{plan * company_{t-1} = plan * company_t\}$)	0.613	0.487	3859
Switched companies (=1)	0.219	0.414	3859
Share of mobile users within household	0.693	0.255	7564
Age (years)	38.199	16.006	7564
Female (=1)	0.491	0.5	7564
Ever mate (=1)	0.654	0.476	7564
Geographical location (Coast=1, Amazon=3)	1.555	0.689	7564
Household monthly income per member (PEN)	663.680	584.358	7344
Maximum education level (max 11 years)	6.482	2.244	7564
Working status (working=1)	0.654	0.476	7564
Student (=1)	0.167	0.373	7564
Worker type (employer=1, employed=2 auto-employed=3, unpaid worker=4)	2.493	0.594	5140
Tenure mobile service (1= less than a year, 4= more than 3 years)	3.232	1.054	7552
Many handsets (yes=1)	0.029	0.167	5439
Many phone numbers (yes=1)	0.039	0.193	5439
Mobile paid by herself/hsh member (=1)	0.986	0.117	7550
Promotions/sales taker (=yes)	0.205	0.404	6538
Internet at home (=1)	0.527	0.499	7047
Internet user (=1)	0.528	0.499	7563
Firm-level information			
Average per-minute price effective per-minute price	0.166	0.047	7546
Share of installed base stations per region	0.403	0.132	7385
Share of port-out lines	0.012	0.015	7546
Market share of lines per region$_{t-1}$	0.544	0.17	7446
Premium of unlocked handset	0.521	0.375	7548
Premium off-net over private network per-minute price	8.102	24.889	7547

Notes: Information given for around 2576 individuals across 2 to 3 years.

Table 5: Demand estimation: log of quantity of minutes consumed as dependent variable

Variables	Random Effects (1)	Fixed effects (2)	First differences (3)
ln(per minute price)	-4.94***	-4.885***	-4.885***
	(0.32)	(0.694)	(0.705)
Inertia	-0.229***	-0.33***	-0.33***
	(0.042)	(0.075)	(0.076)
Premium off-net to private-net per-minute price	-0.009*	-0.015**	-0.015**
	(0.005)	(0.007)	(0.007)
Premium unlocked hansets*switch	-0.227***	-0.401***	-0.401**
	(0.085)	(0.154)	(0.156)
Premium unlocked hansets	-0.872***	-	-
	(0.067)		
Age	0.028***	0.955***	-
	(0.009)	(0.164)	
Female	-0.133***	-	-
	(0.037)		
Ever mate	-0.045	-0.5***	-0.5***
	(0.058)	(0.182)	(0.185)
ln(household monthly income per member)	0.245***	0.128**	0.128**
	(0.032)	(0.052)	(0.053)
Internet at home	0.281***	0.068	0.068
	(0.043)	(0.098)	(0.099)
Use of internet	0.379***	0.201**	0.201**
	(0.046)	(0.085)	(0.086)
Working status	0.116	0.418*	0.418*
	(0.089)	(0.215)	(0.218)
Student	0.129	0.405***	0.405***
	(0.081)	(0.155)	(0.157)
Mobile service tenure	0.059**	-0.169*	-0.169*
	(0.027)	(0.099)	(0.1)
Promotions/sales taker	-0.166***	-0.07	-0.07
	(0.043)	(0.074)	(0.076)
Many phone numbers	0.518***	0.457**	0.457**
	(0.13)	(0.19)	(0.193)
Hsh member/ herself pays bill	0.09	0.501	0.501
	(0.213)	(0.478)	(0.485)
Entel dummy	1.148***	0.782**	0.782**
	(0.181)	(0.323)	(0.328)
Bitel dummy	10.174***	11.376***	11.376***
	(1.287)	(2.557)	(2.595)
Constant	-43.543***	-7.47***	0.955***
	(5.348)	(0.79)	(0.167)
R^2 overall	0.449	0	0.079
R^2 between	0.47	0	0.079
R^2 within	0.348	0.389	-
Std. dev. α_i	0.352	10.782	2.598
Std. dev. ϵ_{ijt}	0.726	0.709	0.983
N. obs	2271	2271	585
N. groups	1686	1686	-

[a] ***, **, * denotes statistic significance at 1%, 5% and 10% level respectively. Robust errors are given in parentheses for all columns.

[b] $ln(p_{jt})$ is instrumented by the lagged log of share of installed base stations, and lagged log of share of port-out lines.

[c] Region fixed-effects are used in column (1) and omitted from the table, as well as other 7 regressors. Given the rejection of the Hausman test, the fixed-effect model, column(2) is the efficient one.