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“Switching Costs in Two-sided Markets”

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Switching Costs in Two-sided Markets*

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Abstract

This paper studies a dynamic two-sided market in which consumers face switching costs between competing products. I first show that, in a symmetric equilibrium, switching costs lower the first-period price if network externalities are strong. By contrast, switching costs soften price competition in the initial period if network externalities are weak and consumers are more patient than the platforms. Second, an increase in switching costs on one side decreases the first-period price on the other side. Finally, consumer heterogeneity such as the presence of more loyal and naive customers on one side intensifies first-period competition on this side but softens first-period competition on the other side.

Keywords: switching costs, two-sided markets, network externality, naivety, loyalty

JEL Classification: D4, L1

> *"High price [and] lack of consumption apps... doomed the Surface. They could have broken through by pricing the Surface aggressively to drive sales volume that created a pull on app developers. But they didn't. Consumers stayed away."*
>
> Hal Berenson, President of True Mountain Group, LLC.[1]

1 Introduction

In many markets, there are switching costs and network effects. Previous work points out that large switching costs cause firms to charge a higher price to their locked-in customers, and large network externalities cause platforms to charge a lower price, yet little is known about the interaction between the two concepts. This paper studies how switching costs affect price competition when network externality is present; I find that an increase in switching costs of one group intensifies price competition for the other group in the introductory period.

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[1] Quoted from "Will Microsoft get the new Surface(s) right? Part 1," `hal2020.com`, May 8, 2014.

A good example is the smartphone operating system market. Apple, Google and Windows are key players in the market. Each of them faces two groups of consumers, application users and application developers. While it is easy for consumers to migrate data from an older version of Windows Phone to a newer version, a consumer who switches from Android to Windows Phone incurs the cost of migrating - if not re-purchasing - a set of apps, media files, as well as contacts, calendars, emails and messages. As suggested by Hal Berenson, one of the problems faced by Windows Phone is its weak app library. Suppose now that Windows improves its library by introducing more Android apps. This not only raises the utility of users through network externality but also lowers their switching cost in terms of data migration. For instance, making some Android movie or music streaming apps available also for Windows Phone allows users to migrate their media files across devices more easily without the hassle of moving the data manually, which results in lower switching costs.[2] Such change may seem to be welfare-improving because the extent to which platforms can exploit their locked-in customers is smaller. However, in markets with cross-group externalities, where participation of one group increases the value of participating for the other group, I show that a decrease in switching costs of the user leads to an increase in the price for developers. Since developers value the participation of the user and a decrease in switching costs of the user makes attracting users easier, the platform can price higher to extract rents from developers. As a consequence, lower switching costs may not improve consumer welfare. It is important that regulators can evaluate the outcome of these cross-group effects properly. The analysis also provides insight into other two-sided markets with switching costs, such as media, credit cards, video games, and search engines.

I consider a simple Hotelling model of duopoly with horizontal differentiation, where platforms 0 and 1 sell their product to consumers whose relative preference for the two platforms are indexed by their position along a unit interval. Consumers have unitary demand, so that in each period, each consumer purchases one good from either platform (single-homing). The penultimate section will extend the analysis to cover the multi-homing case. I assume that there are both switching costs and network externalities. Moreover, consumers are heterogeneous in terms of loyalty and naivety. Loyal consumers are attached to one platform and never switch.[3] Naive consumers are short-sighted and care only about today. This model is flexible enough that it can collapse to either a pure switching-cost model or to a pure two-sided market model for extreme parameter values. When both effects are at work, I show that conventional results may change. I focus on symmetric equilibrium in which platforms charge the same price to each side. I also show that such equilibrium exists even when parameters on the two sides are not symmetric.

This paper's contribution is twofold. First, it studies switching costs together with network

[2]Klemperer (1995) gives many examples of different kinds of switching costs, for instance, learning costs, psychological costs, transactions costs, etc. The UK Office of Fair Trading documented some useful case studies.

[3]A survey published by Consumer Intelligence Research Partners (CIRP) reveals that almost half of smartphone buyers stay loyal to their previous brand, with Apple having the highest loyalty rate. This survey was taken from data surveying 500 subjects in the US who had purchased a new mobile phone in the previous 90 days over the last four quarters, between July 2012 and June 2013.

externalities, whereas the existing literature has tended to focus on either of them. Discussing the two together is important - I show that switching costs work differently in a two-sided market and this result has important implications for consumer protection. In a one-sided market, switching costs may intensify or soften first-period price competition depending upon how patient consumers are relative to platforms; but in a two-sided market, under strong externalities, higher switching costs always make the first-period more competitive. I also find that there is a cross-effect: higher switching costs on one side unambiguously reduce the price on the other side. The second contribution relates to the investigation of consumer heterogeneity that has been neglected in the two-sided market literature. In particular, this model provides a general framework for examining how switching costs affect the pricing strategy of platforms depending on consumers' characteristics, such as sophistication and loyalty, which traditional arguments cannot deal with.

The main results can be summarized as follows. When cross-group externalities are weak, whether higher switching costs make the market more competitive in the first period depends on two forces. On the one hand, more patient consumers are less tempted by a temporary price cut because they understand that the price cut will be followed by a price rise in later periods. Their demand is therefore less elastic, and platforms will respond by charging higher prices. On the other hand, more patient platforms put more weight on future profits, and thus both compete aggressively for market share. Switching costs make markets more competitive if platforms are relatively more patient than the consumers. By contrast, when externalities become sufficiently strong, platforms' incentive to lock consumers in becomes stronger because by capturing one group of consumers, it helps to convince the other group to join. Consequently, higher switching costs cause the platform to charge a lower price in the first period. Additionally, there is a cross-group effect: an increase in switching costs on one side unambiguously decreases the price on the other side. The reason is that platforms can build market share either directly through one side or indirectly through the other side. When switching costs on one side are large, an easier way to build market share is to focus on the indirect channel; consequently first-period competition is increased on the other side (Proposition 5).

Considering consumer heterogeneity, I show that platforms offer lower prices to one side if there are many naive and loyal consumers. The intuitive reason is that after consumers make their purchase in the first period, consumers who are loyal know that they will patronize the same platform for an indefinite period of time, and feel that they deserve a bigger carrot in the first period. The presence of naive consumers, who care only about immediate cost and reward, gives even more incentive to platforms to compete aggressively. Platforms charge higher prices to one side if on the other side there are more naive consumers. This is because higher price elasticity on the side with more naive consumers reduces the opportunity cost of recruiting consumers on the other side. Therefore, it leads to less competitive behavior on the other side (Proposition 7).

These results yield clear policy recommendations. First, since asymmetric price structures are common in two-sided markets, attractive introductory offers do not necessarily call for consumer protection as in one-sided markets. Second, if disloyal consumers do not know their preferences in the first period, platforms may provide imprecise information about their tastes, so that these consumers are less loyal, and they will switch more, which platforms can exploit later. Therefore, there is room for government intervention, particularly in achieving a greater transparency of information. Disloyal consumers would benefit from more information, so that they are able to make choices that are best aligned to their tastes. As a result, they can build loyalty more easily and save considerable switching costs.

1.1 Related Literature

There is a sizeable literature on switching cost, which broadly speaking, can be categorized into two main groups.[4] One group of papers assumes that firms cannot discriminate between old and new consumers. Firms knowing that they can exercise market power in the second period over those consumers who are locked-in, they are willing to charge a lower price in the first period in order to acquire these valuable customers. This "bargains-then-ripoff" pattern is the main result of the first-generation switching-cost models (see for instance Klemperer (1987a, b)). A second group of works allows for price discrimination, so firms can charge a price to its old customers and a different price to new ones. Chen (1997) analyzes a two-period duopoly with homogeneous goods. Under duopoly, consumers who leave their current supplier have only one firm to switch to. Since there is no competition for switchers, this allows the duopolist to earn positive profits in equilibrium. Taylor (2003) extends Chen's model to many periods and many firms. With three or more firms, there are at least two firms vying for switchers, and if products are undifferentiated, these firms will compete away all their future profits. More recent contributions include Biglaiser, Crémer and Dobos (2013), which studies the consequence of heterogeneity of switching costs in an infinite horizon model with free entry. They show that even low switching cost customers are valuable for the incumbent.

The design of pricing strategies to induce agents on both sides to participate has occupied a central place in the research on two-sided markets.[5] The pioneering work is Caillaud and Jullien (2003), who analyze a model of imperfect price competition between undifferentiated intermediaries. In the case where all agents must single-home, the only equilibrium involves one platform attracting all agents and the platform making zero profit. In contrast, when agents can multi-home, the pricing strategy is of a "divide-and-conquer" nature: the single-homing side is subsidized (divide), while the multi-homing side has all its surplus extracted (conquer). Armstrong (2006) advances the analysis by putting forward a model of competition between differentiated platforms by using the Hotelling specification. He finds that the equilibrium price is determined by the magnitude of cross-group externalities and whether agents single-home or multi-home. His approach is the closest to mine. However, he focuses on a static model of two-sided market without switching costs, while here with switching costs and different degrees of sophistication the problem becomes a dynamic one. Another closely related paper is Rochet and Tirole (2006), who combine usage and membership externalities (as opposed to the pure-usage-externality model of Rochet and Tirole (2003), and the pure-membership-externality

[4]Farrell and Klemperer (2007), and Klemperer (1995) provide excellent overviews on the literature of consumer switching costs.

[5]See Rysman (2009) for a survey of the literature on two-sided markets.

model of Armstrong (2006)), and derive the optimal pricing formula. But they focus on the analysis of a monopoly platform.

Substantial studies have been separately conducted in the dual areas of switching costs and two-sided markets, but analysis is rarely approached from a unified perspective. This paper seeks to fill the gap. Besides this study, there is little literature that studies the interaction between switching-costs and network externalities. Su and Zeng (2008) analyze a two-period model of two-sided competing platforms. Their focus is on the optimal pricing strategy when only one group of agents has switching costs and their preferences are independent, while this paper studies a richer setting in which both sides bear switching costs, and consumers are heterogeneous in terms of loyalty and naivety. Therefore, one can view Su and Zeng (2008) as a special case of my model. Biglaiser and Crémer (2014) study the effect of switching costs and network externalities on competition, but they do not address the issue in a two-sided context.

2 Model

Consider a two-sided market with two periods. There are two groups of consumers, denoted A and B, such as smartphone users and application developers. Assume that for some exogenous reasons in each period consumers choose to single-home. Section 5.1 will extend the analysis to cover the multi-homing case. Both sides of consumers have switching costs: side i (A or B) consumers have to incur switching cost $s_i \geq 0$ if they switch platform in the second period. On each side, consumers are heterogeneous in two dimensions. First, consumers can be naive or rational. Naive consumers, who are a fraction α_i of the population on side i, make decisions based on their first-period utility; while rational consumers, who form a fraction $1 - \alpha_i$ of side i's population, make decisions based on their lifetime utility. Therefore, on each side, naive consumers have $\delta_i = 0$, while rational consumers have $\delta_i > 0$.[6] Moreover, I distinguish the firm's discount factor, denoted δ_F, from the consumer's discount factor δ_i. Second, consumers learn whether they are loyal or not after their purchase in the first period. With probability μ_i consumers' preferences do not change and they never switch ("loyal"), and with probability $1-\mu_i$ their preferences are re-distributed on the unit interval in the second period (independent preferences).[7] Independent preferences are needed for technical reason because it smooths the demand function. Since not all consumers have changing preferences in practice, I assume that there are some loyal consumers. There are two competing platforms, denoted 0 and 1, which enable the two groups to interact. Consider a simple Hotelling model, where consumers on

[6]This is different from Klemperer (1987b) because he does not consider the possibility of having a mixture of naive and rational consumers. Consumers are either all naive or all rational.

[7]Loyalty in this model can be interpreted in two ways: First, it can be interpreted as exogenous. Loyal consumers are not able to switch because they have large switching costs. Second, loyalty can be interpreted as endogenous. Suppose that switching cost is drawn from a two-point distribution: s is small with probability $1 - \mu$, and s is big with probability μ. In this case, the concept of loyalty is endogenized because it is determined by switching costs. Both interpretations lead to the same calculations, but for simplicity I adopt the first interpretation for the rest of the analysis.

Klemperer (1987b) makes a similar assumption, but he assumes that those consumers, who have fixed tastes, respond to prices in both periods.

each side are assumed to be uniformly located along a unit interval with the two platforms located at the two endpoints. Both α_i and μ_i are known by the platforms. Throughout the paper, we assume that platforms cannot price discriminate among his previous customers and customers who have bought the rival's product in the previous period.

The utility of a consumer on side i is

$$v_i + e_i n^j_{k,t} - |x - k| - p^i_{k,t},$$

where $i, j \in \{A, B\}, i \neq j$ since the two sides are symmetric. v_i is the intrinsic value of consumers on side i for using either platform. Assume that v_i is sufficiently large such that the market is fully covered. e_i is the benefit that consumer from side i enjoys from interacting with each agent on the other side (for simplicity, I ignore the possibility that consumers also care about the number of people in the same group who joins the platform). Suppose that each side is of mass 1, so that $n^i_{k,t}$ is the number of agents from side i (A or B) who are attached to platform k (0 or 1) in period t (1 or 2), while the number of agents from the same side in the same time period who are attached to the other platform is denoted $1 - n^i_{k,t}$. Thus, $e_i n^j_{k,t}$ is the total external benefit from interacting with the other group. The location of the consumer is denoted x. To keep things simple, I assume unit transport cost. Thus, $|x - k|$ is the transport cost when the consumer purchases from platform k. Platform charges are levied on a lump-sum basis: each agent from side i incurs a cost of $p^i_{k,t}$ when he joins platform k at time t.

Platform k's profit at time t is given by

$$\pi_{k,t} = p^A_{k,t} n^A_{k,t} + p^B_{k,t} n^B_{k,t}, \tag{1}$$

which is the sum of revenues from side-A and side-B. I make three assumptions. First, assume that the marginal cost of production is equal to zero for simplicity. Second, assume that $s_i \in [0, 1)$, where one is the unit transport cost, so that at least some consumers will switch. Third, assume $e_i \in [0, 1)$ in order to ensure that the profit function is well-defined, and the demand is decreasing in a platform's own price and increasing in its rival's price.[8]

The timing of the game is as follows.

- In the first period, consumers are unattached. They learn their preferences. Platforms set the first-period price. Consumers choose which platform to join.

- In the second period, consumers learn their switching cost and whether they are loyal or not.[9] Platforms set the second-period price. Consumers decide to switch or not.

The solution concept for the game is subgame perfect equilibrium (SPE).

[8]More specifically, one represents the unit transport cost. Assuming $e_i < 1$ ensures that in the symmetric equilibrium, both platforms serve some consumers.

[9]The analysis is the same even if consumers learn their switching cost in the first period. However, if they know whether they are loyal or not in the first period, the calculation changes slightly, but qualitative results should hold.

2.1 Second Period: the mature market

I work backward from the second period, where each platform has already established a customer base. Given the first-period market shares $n_{0,1}^A$ and $n_{0,1}^B$, a consumer on side i, located at θ_0^i on the unit interval, purchased from platform 0 in the first period is indifferent between continuing to buy from platform 0 and switching to platform 1 if

$$v_i + e_i n_{0,2}^j - \theta_0^i - p_{0,2}^i = v_i + e_i(1 - n_{0,2}^j) - (1 - \theta_0^i) - p_{1,2}^i - s_i.$$

The indifferent consumer is given by

$$\theta_0^i = \frac{1}{2} + \frac{1}{2}[e_i(2n_{0,2}^j - 1) + p_{1,2}^i - p_{0,2}^i + s_i].$$

Another consumer on side i, positioned at θ_1^i, previously purchased from platform 1 is indifferent between switching to platform 0 and continuing to purchase from platform 1 if

$$v_i + e_i n_{0,2}^j - \theta_1^i - p_{0,2}^i - s_i = v_i + e_i(1 - n_{0,2}^j) - (1 - \theta_1^i) - p_{1,2}^i.$$

The indifferent consumer is given by

$$\theta_1^i = \frac{1}{2} + \frac{1}{2}[e_i(2n_{0,2}^j - 1) + p_{1,2}^i - p_{0,2}^i - s_i].$$

We then substitute θ_0^i and θ_1^i into the following.

$$n_{0,2}^i = \mu_i n_{0,1}^i + (1 - \mu_i)n_{0,1}^i\theta_0^i + (1 - \mu_i)(1 - n_{0,1}^i)\theta_1^i. \tag{2}$$

Consumers of platform 0 consists of three types, and similarly for platform 1. The first type is loyal customers, who buy from platform 0 in both periods. The second type is switchers (whose preferences are unrelated in the two periods), who did not switch away from platform 0. The third type is also switchers, but they switched away from platform 1 to platform 0.

Then, we solve for the market shares, plug them into the profit functions, and solve for the equilibrium prices. The details are shown in Appendix A.

2.1.1 Effect of Switching Costs on Second-period Pricing

Proposition 1. *Given first-period market share, on each side, the platform with a larger market share increases the second-period price as switching costs increase; whereas the other platform with a smaller market share decreases the second-period price as switching costs increase.*

Proof. See Appendix A.1. □

The literature calls this price a "ripoff" because the second-period price paid by consumers in equilibrium is higher in a market with switching costs than in a market without switching costs.[10] However, the extent of the ripoff depends on market share. There are two possible strategies: On the one hand, the platform might want to exploit its existing customers with

[10] As will be seen later, the second-period price in my model is $p_{0,2}^i = \frac{1-e_j(1-\mu_i)}{1-\mu_i}$, which is larger than the price in a two-sided market model without switching costs, $p^i = 1 - e_j$.

a high price because switching costs give platform market power over the consumers who are locked-in. On the other hand, the platform might want to poach its rival's customers with a low price. Proposition 1 shows that the platform with a larger market share charges a higher second-period price as switching costs increase because it focuses more on exploiting old customers than on poaching new customers; whereas the platform with a smaller market share charges a lower second-period price in order to win back some customers.

Notice that if the market share is equal between platforms, then switching cost has no effect on the second-period price, which is indeed the case when we solve the full equilibrium. The reason is that when platforms have an equal share of the market, their incentives to exploit old customers offset their incentives to attract new customers.

Proposition 2. *Given first-period market share, the second-period price paid by consumers on side i is increasing in switching costs of consumers on side j if*

(i) Consumers on side j are more valuable ($e_i > e_j$), and platform 0 has a larger market share on side j ($n_{0,1}^j > 1/2$), or

(ii) Consumers on side i are more valuable ($e_i < e_j$), and platform 0 has a smaller market share on side j ($n_{0,1}^j < 1/2$).

Proof. See Appendix A.2. □

The intuition behind Proposition 2 runs as follows. Part (i) shows that consumers on side j are more valuable to the platform because they exert stronger externalities on consumers on side i compared to externalities of side i on side j. If the platform has a larger market share of the more valuable side, it can charge higher second-period prices to both sides compared to the case without switching costs. That is, $\partial p_{0,2}^j / \partial s_j > 0$ from Proposition 1, and $\partial p_{0,2}^i / \partial s_j > 0$ from (i) of Proposition 2.

By contrast, part (ii) shows that if the platform has a smaller market share of side j, according to Proposition 1 it will focus more on poaching side j with a low price than exploiting them with a high price, that is, $\partial p_{0,2}^j / \partial s_j < 0$. It will then charge a higher second-period price to side i because decreasing the price on side j reduces the "opportunity cost" of recruiting consumers on side i: the platform loses less revenue on side j by recruiting one less consumer on side i.[11] Both platforms thus compete less aggressively for them. Consequently, higher switching costs on side j cause the platform to charge a higher price on side i, that is, $\partial p_{0,2}^i / \partial s_j > 0$. Note that what platform 1 will do is just the opposite of platform 0 because of the asymmetric market shares.

In a one-sided market with switching costs, a platform's market share is an important determinant of its pricing strategy because it affects the platform's future profitability (see

[11] Rochet and Tirole (2003, 2006) explain that the difference between a one-side market and a two-sided market lies in the change in this opportunity cost. In particular, the standard Lerner formula becomes

$$\frac{p^i - (c - p^j)}{p^i} = \frac{1}{\eta^i}$$

in a two-sided market, where c is the marginal cost and η is the price elasticity.

Klemperer (1995)); in a multi-sided market it is crucial to also take into consideration network externalities. Relying on a one-sided logic may overestimate potential anti-competitive effects: according to Proposition 1 the second-period price tends to increase with switching cost on the side that the platform has a larger market share; but this does not necessarily imply anti-competitive motives in two-sided markets, since according to Propositions 2 larger margin on one side could be translated into smaller or even negative margin on the other side depending on the magnitude of externalities.

2.1.2 Effect of Switching Costs on Second-period Profit

Consider the case, where (i) the platform's first-period market shares of the two sides are not too small, and (ii) cross-group externalities are not too different from each other.

Proposition 3. *Platform's second-period profits are increasing in switching costs on one side if it has a larger market share on this side than the other platform, and decreasing in switching costs if it has a smaller market share.*

Proof. See Appendix A.3. □

In the literature, switching costs typically raise platforms' profits in the second period of a market with switching costs as compared to a market without switching costs because platforms charge a higher price to repeat buyers. However, Proposition 3 shows that whether second-period profits increase or decrease with switching costs depends on market share and cross-group externalities.

2.2 First Period: the new market

I now turn to the first-period equilibrium outcomes when consumers are unattached. All consumers have discount factor δ_i. However, on side i, a proportion α_i of consumers are naive (N) with $\delta_i = 0$. They make decisions based on their first-period utility only. A proportion $1 - \alpha_i$ of side i's population is rational (R) with $\delta_i > 0$. They make decisions based on their lifetime utility.

A naive consumer on side i located at θ_N^i is indifferent between buying from platform 0 and platform 1 if

$$v_i + e_i n_{0,1}^j - \theta_N^i - p_{0,1}^i = v_i + e_i(1 - n_{0,1}^j) - (1 - \theta_N^i) - p_{1,1}^i,$$

which can be simplified to

$$\theta_N^i = \frac{1}{2} + \frac{1}{2}[e_i(2n_{0,1}^j - 1) + p_{1,1}^i - p_{0,1}^i].$$

As for sophisticated consumers, they also take into consideration their second-period utility. If a sophisticated consumer on side i located at θ_R^i joins platform 0 in the first period, his expected second-period utility is given by

$$U_{0,2}^i = \mu_i(v_i + e_i n_{0,2}^j - \theta_R^i - p_{0,2}^i) + (1 - \mu_i)\int_0^{\theta_0^i}(v_i + e_i n_{0,2}^j - \theta_R^i - p_{0,2}^i)dx$$
$$+ (1 - \mu_i)\int_{\theta_0^i}^1(v_i + e_i(1 - n_{0,2}^j) - (1 - \theta_R^i) - p_{1,2}^i - s_i)dx.$$

$U_{0,2}^i$ is the sum of three terms. With probability μ_i the consumer is loyal and chooses to join platform 0 in both periods; with probability $(1-\mu_i)\theta_0^i$ he has independent preferences but still chooses to stay with platform 0; and with probability $(1-\mu)(1-\theta_0^i)$ he has independent preferences and he switches to platform 1.

Similarly, if he joins platform 1 in the first period, his expected second-period utility is given by

$$\begin{aligned} U_{1,2}^i = \mu_i(v_i + e_i(1-n_{0,2}^j) - (1-\theta_R^i) - p_{1,2}^i) \\ + (1-\mu_i)\int_{\theta_1^i}^{1}(v_i + e_i(1-n_{0,2}^j) - (1-\theta_R^i) - p_{1,2}^i)dx \\ + (1-\mu_i)\int_0^{\theta_1^i}(v_i + e_i n_{0,2}^j - \theta_R^i - p_{0,2}^i - s_i)dx. \end{aligned}$$

A sophisticated consumer on side i is indifferent between purchasing from platform 0 and platform 1 if

$$v_i + e_i n_{0,1}^j - \theta_R^i - p_{0,1}^i + \delta_i U_{0,2}^i = v_i + e_i(1-n_{0,1}^j) - (1-\theta_R^i) - p_{1,1}^i + \delta_i U_{1,2}^i.$$

After some rearrangement, this gives

$$\theta_R^i = \frac{1}{2} + \frac{1}{2}[e_i(2n_{0,1}^j - 1) + p_{1,1}^i - p_{0,1}^i + \delta_i(U_{0,2}^i - U_{1,2}^i)].$$

The first-period market share of side i is

$$n_{0,1}^i = \alpha_i\theta_N^i + (1-\alpha_i)\theta_R^i. \tag{3}$$

Then, we can derive the profit functions, and solve for the equilibrium prices. Calculations are rather involved and interested readers can refer to Appendix B.

I focus on the platform-symmetric equilibrium: both platforms charge the same price to each side, that is, $p_{0,1}^A = p_{1,1}^A$ and $p_{0,1}^B = p_{1,1}^B$.

Proposition 4. *The single-homing model has a symmetric equilibrium.*

Proof. See Appendix B. □

Although I focus on a symmetric equilibrium, the existence of it does not require all parameters on the two sides to be symmetric. I show the existence condition, Equations (B.1) and (B.2), in Appendix B. In the next section, I will discuss the comparative statics of the price.

3 Discussion

The analysis of the effect of switching costs on first-period prices is complicated as several effects are at play. An easier way to interpret the result is to start the discussion from pure switching-cost model (à la Klemperer) and pure two-sided market model (à la Armstrong), and then turn to the main model of the paper: a two-sided market model with switching costs. In addition, I will study other interesting ingredients such as loyalty and naivety.

3.1 Pure Switching-cost Model

In a one-sided market with switching costs, all consumers are rational; network externalities and consumers' loyalty do not matter. Assuming that $\alpha_i, \mu_i, e_i = 0$, $i \in \{A, B\}$, the first-period equilibrium price becomes

$$p^i_{0,1} = 1 + \frac{2}{3}(\underbrace{\delta_i s_i^2}_{consumer's\ anticipation} - \underbrace{\delta_F s_i}_{firm's\ anticipation}),$$

which is equivalent to Equation (18) in Klemperer (1987b).

Since the level of the first-period price is lower in a market with switching costs than without them, the literature calls it a "bargain". This pattern of attractive introductory offers followed by higher prices to exploit locked-in consumers (see Proposition 1) - the "bargains-then-ripoffs" pricing - is well-known in the switching-cost literature.

However, the extent of the bargain depends on switching costs. More specifically, the first-period price is U-shape in switching costs. There are two effects at work: On the one hand, rational consumers anticipate that if they are locked-in in the second period, the platform will raise its price. Thus, consumers are less responsive to a first-period price cut. This explains why consumers' sophistication increases the first-period price through δ_i. On the other hand, forward-looking platforms have strong incentive to invest in market share because they anticipate the benefit of having a larger customer base in the future. Platforms thus compete more aggressively to capture market share, and platforms' sophistication decreases the first-period price through δ_F. While the platform's anticipation effect is first-order in switching costs, the consumer's anticipation effect is only second-order. Therefore, the platform's anticipation effect dominates initially, the first-period price decreases with switching costs; and later the consumer's anticipation effect becomes more powerful, and thus the first-period price increases with switching costs.[12] Consequently, we get the U-shape relationship.

3.2 Pure Two-sided Market Model

In a simple model of two-sided markets, there is only one period, so that $\delta_F, \delta_i, \alpha_i = 0$; and loyalty and switching costs are irrelevant, so that $s_i, \mu_i = 0$, $i \in \{A, B\}$.

The first-period equilibrium price is simplified to

$$p^i = 1 - e_j,$$

which is the same as in Proposition 2 of Armstrong (2006). This equation shows that platforms compete fiercely for the more valuable group, whose external benefit exerted on the other group of consumers is larger.

[12] Different papers use different terminologies, for example, Somaini and Einav (2013) use "anticipation effect" and "investment incentive", while Rhodes (2013) uses "consumer elasticity effect" and "investment effect". I simply call them consumer's and firm's anticipation effect because the mechanism goes through the discount factor. My paper is quite different from Somaini and Einav (2013) and Rhodes (2013): they examine the effect of switching costs in a dynamic setting without network externalities, while I discuss a model with both switching costs and network externalities.

3.3 Switching Costs in Two-sided Markets

More generally, in a two-sided market with switching costs, I find that the "bargain" can be increasing in switching costs when externalities are strong, which is different from Klemperer's result. This model is a good representation of markets such as smartphone and video games. Smartphone: switching from Apple's iOS to Google's Android system, application developers need to re-code their programs for different interfaces, as well as to create additional support and maintenance; whereas application users need to migrate and re-purchase their applications. Video games: switching from Sony's PlayStation to Windows' Xbox, gamers need to re-learn how to use the controller and lose the progress of their games, whereas developers have to buy a separate development kit to create games for different consoles.

Proposition 5. *In the single-homing model, with all consumers and both platforms equally rational, $\delta_i = \delta_F = \delta > 0$ and $\alpha_i = 0$; independent preferences, $\mu_i = 0$; and symmetric externalities, $e_i = e > 0$, $i \in \{A, B\}$,*

i. If externalities are weak, on each side the first-period price $p^i_{0,1}$ is U-shape in switching costs s_i.

ii. If externalities are strong, on each side the first-period price $p^i_{0,1}$ is decreasing in switching costs s_i.

iii. The first-period price charged to side i, $p^i_{0,1}$, is decreasing in switching costs on side j, s_j.

Proof. See Appendix C. □

As in Klemperer (1987b), the first-period price is lower with switching costs than without, which represents a bargain. This paper, however, finds that the extent of the bargain depends not only on switching costs on one side, but also on externalities and switching costs on the other side.

More specifically, part (i) shows that when externalities are weak, we get the result of Klemperer: the bargain is inverted U-shape in switching costs. For small switching costs, rational consumers understand that they can easily switch in the second period, and are therefore more responsive to price cut in the first period. Platforms have strong incentive to compete for market share. Consequently, switching costs are pro-competitive when they are small. By contrast, when switching costs are very large, rational consumers recognize that they will be exploited in the second period, and are therefore less tempted by a price cut. Their demand becomes less elastic, and platforms will respond by charging higher prices. This explains why switching costs are anti-competitive when they are large.

Interestingly, part (ii) shows that strong externalities overturn the U-shape result: in this case the bargain is increasing in switching costs, and the positive relationship between the first-period price and switching costs does not arise. The intuition is that externalities provide an additional downward push on the first-period price because recruiting one side helps to get the other side on board. This strengthens the incentives of platforms to invest in market share, which dominates the incentive of rational consumers to avoid being locked-in. Consequently, switching costs always make the market more competitive when externalities are strong.

Part (iii) shows that an increase in switching costs on one side unambiguously decreases the first-period price charged to the other side. The reason is that platforms can build market share on side j via two channels: directly through side j, and indirectly through side i. When switching costs on side j are large, rational consumers are less responsive to price cuts because they expect a price rise to follow in the second period. An easier way to build market share on side j is then to focus on the indirect channel, i.e. attracting side i. As a result, first-period competition is increased on side i.

Proposition 5 also provides new insights into the two-sided market literature. While Armstrong (2006) shows that prices are decreasing in externalities, I focus on the effect of the interaction between network externalities and switching costs on prices.

3.4 Naive Consumers

A straightforward interpretation of naive consumers is that these consumers only care about utility in the current period. Or this could also be interpreted as the case in which consumers are different in every period.[13]

Proposition 6. *In the single-homing model, when all consumers are naive, $\delta_i = 0$ and $\alpha_i = 1$; and have independent preferences, $\mu_i = 0$, $i \in \{A, B\}$, the first-period price $p^i_{0,1}$ is decreasing in switching costs s_i regardless of the level of externalities.*

Proof. See Appendix D □

The intuition underlying this proposition is as follows. When consumers are naive, they do not anticipate that a first-period price cut will lead to a second-period price rise, and will therefore react more responsively to price cut in the first period. This increases the incentives of platforms to reduce the first-period price in order to gain more market share. Since naive consumers have no incentive to avoid being locked-in, the platform's incentive to compete for market share dominates. This explains the fierce price competition for naive consumers.

Strictly speaking, expectation about whether the others will switch play no role here because μ_i and α_i are known. In a broader sense, however, Proposition 6 can be interpreted as in line with earlier work by von Weizsäcker (1984) and Borenstein, MacKie-Mason and Netz (2000). They show that if consumers expect that a firm's price cut is more permanent than their tastes, which can be interpreted as consumers being naive, then switching costs tend to lower prices.

3.5 Heterogeneous Consumers

I now turn to discuss, rather than having all consumers being rational or naive, the consequence of having heterogeneous consumers. On each side, a fraction α_i of consumers are naive, while

[13] For example, a company buys some software for their workers in the first period. Some workers leave the company in the second period, and purchase their own software. These workers have a switching cost of learning some new software that are different from that purchased by their company, but the company will not take into consideration this switching cost when buying in the first period.

$1 - \alpha_i$ of them are rational; and a proportion μ_i consumers are loyal, while the remaining ones have independent preferences.[14]

Proposition 7. *In the single-homing model,*

i. On each side, the first-period price $p^i_{0,1}$ is decreasing in the proportion of naive consumers α_i, if the proportion of loyal consumers, μ_i, is high.

ii. The first-period price on side i, $p^i_{0,1}$, is increasing in the proportion of naive consumers on side j, α_j.

iii. The first-period price $p^i_{0,1}$ is decreasing in the discount factor of the platform δ_F.

Proof. See Appendix E. □

The intuition behind this proposition is as follows. Part (i) shows that on each side, if there are many loyal consumers, the first-period price is lower with naive consumers than without.[15] The reason is that after consumers make their purchase in the first period, consumers who are loyal know that they will patronize the same platform for an indefinite period of time, and feel that they deserve a bigger carrot in the first period. Naive consumers, who care only about today, are more attracted by a price cut. Therefore, increasing the proportion of consumers who are loyal and naive makes the market more competitive in the first period.

Part (ii) shows that an increase in the proportion of consumers who are naive on one side will soften price competition on the other side. Intuitively, the demand of naive consumers on side j is more elastic, and platforms will react by charging lower prices. This, in turn, reduces the opportunity cost of recruiting consumers on side i. Platforms thus compete less aggressively for market share on side i. Consequently, consumers' naivety on one side mitigates the ferocity of first-period competition for market share on the other side.

Part (iii) shows that first-period prices are lower when platforms are more patient. Platforms compete harder on prices because they foresee the advantage of having a large customer base in the future.

More generally, Propositions 5 and 7 say that the strategy of lowering price is not simply due to network externalities in a two-sided market, a view that is central to the work of Rochet and Tirole (2003), and Armstrong (2006). But in my model whether the platform will act more aggressively also depends on the characteristics of consumers and their switching costs. This has important implications on regulations that alter switching costs and loyalty rate in real circumstances, which will be explored more fully in Section 4.

[14] Gabszewicz, Pepall and Thisse (1992) also discuss heterogeneous consumers in terms of brand loyalty, but they consider the pricing strategy of a monopoly incumbent, who anticipates the entry of a rival in the subsequent period, and focus on the effect of loyalty on entry.

[15] If consumers' tastes change ($\mu < 1$), it may nullify the competitive effect of naivety.

3.6 A Special Case: asymmetric sides

The model also covers the case of asymmetric sides, where consumers on one side, say side-B, do not incur any switching costs in the second period ($s_B = 0$). Examples of such a market include browsers, search engines, and shopping malls. Browsers: Internet users can switch relatively more easily between Internet Explorer, Chrome, and Firefox than content providers because when content providers switch, they need to rewrite the codes so that they are compatible with the new browser. Search engines: customers can switch easily between Google, Bing and Yahoo in as little as one click, but there are switching costs for top-listed publishers, who want their website to appear on the top list of another search engine. Shopping malls: shoppers are free to go to any shopping malls, but there are high transaction costs for shops in terminating the old contract and initiating a new one.

For simplicity, assume that consumer preferences are independent, $\mu_i = 0$; all consumers are rational, $\alpha_i = 0$; and they have the same discount factor as the firm, $\delta_i = \delta_F = \delta$, $i \in \{A, B\}$.

Corollary 1. *If only one side of consumers has switching costs, then switching costs only affect the price on this side but not the other side.*

Proof. Under the assumptions above,

$$p_{0,1}^B = 1 - e_A.$$

□

The intuition is that since preferences of side-B consumers in the two periods are unrelated and they do not have switching costs, every period's choice is independent. This means that the first-period price is not affected by the second-period price. Consequently, although side-A consumers' switching costs affect side-B's second-period price through externalities, it does not affect side-B's first-period price.

3.7 Effect of Switching Costs on First-period Profit

In a platform-symmetric equilibrium, the two platforms share consumers on each side equally, that is $n_{0,1}^A = n_{0,1}^B = 1/2$. Therefore, the expected profit of platform 0 is

$$\pi_0 = \frac{1}{2} p_{0,1}^A + \frac{1}{2} p_{0,1}^B + \delta \pi_{0,2},$$

where $\pi_{0,2}$ is the second-period profit.

Differentiating π_0 with respect to s_i, we obtain

$$\frac{\partial \pi_0}{\partial s_i} = \frac{1}{2} \frac{\partial p_{0,1}^i}{\partial s_i} + \frac{1}{2} \frac{\partial p_{0,1}^j}{\partial s_i}$$

because the profit in the last period, $\pi_{0,2}$, is not affected by s_i in equilibrium.

As is well-known from the switching-cost literature, switching costs raise platforms' profits in the second period compared to the case of no switching costs as second-period prices are usually higher. However, the presence of market power over locked-in consumers intensifies competition in the first period, and this may result in a decrease in overall profit.[16]

More interestingly, I identify an additional channel through which switching costs can reduce overall profit, namely, when network externalities are strong. The reason is that strong externalities increase the incentives of platforms to vie for market share, and therefore switching costs on side i intensify price competition on side i (see (ii) of Proposition 5). Higher switching costs on side i also lead to more competitive behavior on side j because capturing more consumers on side j is a cheaper way to build market share on side i. Side i consumers are harder to attract as they have strong incentives to avoid being locked-in and thus paying large switching costs in the second period (see (iii) of Proposition 5). Higher switching costs lower prices on both sides, and thereby reducing overall profit.

4 Welfare and Policy Implications

The first-period welfare is constant in switching costs because all consumers buy one unit of good, the size of the two groups is fixed, and the whole market is served. It ignores the possible demand-expansion and demand-reduction effects of switching costs as the total demand is fixed. However, the second-period welfare is decreasing in switching costs. The welfare loss is the sum of two deadweight losses:

$$2(1-\mu_i)[\quad \underbrace{(\frac{1-s_i}{2})s_i}_{DWL\ from\ switchers} \quad + \quad \underbrace{\frac{s_i^2}{4}}_{DWL\ from\ non-switchers} \quad].$$

Consider consumers who have independent preferences. Since their tastes will change in the second period, for those who have previously bought from platform 0, consumers whose tastes change a lot will switch to platform 1 with probability $(1-s_i)/2$ and each pays s_i; consumers whose tastes change a little will continue to buy from platform 0 even though they prefer platform 1. This happens with probability $s_i/2$ and each suffers an average loss of mismatch with an inferior product $s_i/2$. Similarly, consider consumers who have previously bought from platform 1. Consumers on both sides suffer this loss. As for loyal consumers, there is no loss for them because first, they do not switch; second, their preferences do not change, and hence there is no deadweight loss associated with mismatch.[17]

Although switching costs lower social welfare, from the consumer welfare point of view, consumers may still benefit from switching costs if the equilibrium price is lower. I therefore suggest the following policy implications. In one-sided markets, attractive introductory offers that induce early adoption may call for consumer protection in later periods, for example, through compatibility or standardization policies that lower switching costs. In two-sided markets, asymmetric price structures are common because they help to increase the participation

[16] See for instance Klemperer (1987a).

[17] Naivety does not affect welfare. The only thing that matters for welfare is whether consumers' preferences change or not. When consumers' preferences do not change, they make the right product choice and do not switch. When consumers' preferences change, switchers have to incur the switching costs, and some of the non-switchers are forced into buying an inferior product that does not match their tastes.

of different groups of consumers. For example, Proposition 2 shows that s_j may have a positive or negative impact on $p^i_{0,2}$, and Proposition 5 shows that the relationship between $p^i_{0,1}$ and s_i depends on e, and $p^i_{0,1}$ decreases with s_j. Therefore, when policy-makers alter switching costs of one group, it may have broader repercussions on the other group; sticking to a one-sided logic may lead to inefficient policies.[18]

In this model, I assume that all consumers know their preferences in the current period, but tastes of some consumers may change. One could alternatively interpret a fraction μ_i of consumers know their preferences, while $1-\mu_i$ of them do not know theirs. Disloyal consumers receive a signal about their tastes in the first period, and after buying from the platform, they know their tastes in the second period. This would not change the result as long as the signal is uniformly distributed. This allows us to evaluate the effect of information transparency policy. For example, Proposition 7 shows that loyalty makes it more likely that naivety will hurt the platform. Thus, platforms may lack incentive to enhance consumers' understanding of their own preferences. They might try to provide imprecise information about consumers' tastes, so that consumers are less loyal, and they will switch more, which platforms can exploit later. Therefore, there is room for government intervention. In particular, increasing transparency of information would enable disloyal consumers to make choices that are best aligned to their tastes, build loyalty and save switching costs.

5 Extensions

The analysis so far is based on a single-homing model, but this is not the only market configuration in reality. There are various ways to extend the model, for instance, one may consider the case where one group single-homes while the other group join both (commonly termed as "competitive bottlenecks"). It might also be interesting to consider asymmetric platforms. I will sketch these extensions in turn.

5.1 Competitive Bottlenecks

Suppose that side A continues to single-home, while side B may multi-home. Competitive bottleneck framework is typical in markets such as computer operating systems, and online air ticket and hotel bookings. Operating systems: users use a single OS, Windows OS, Apple's Mac OSX platform or Linux-based OS, while engineers develop software for different OS. Travel bookings: consumers use one comparison site such as skyscanner.com, lastminute.com or booking.com, but airlines and hotels join multiple platforms in order to gain access to each comparison site's customers. Since side B can join both platforms, switching costs and loyalty on this side are not relevant, so that $s_B, \mu_B = 0$.[19] The main difference from the single-homing

[18] Wright (2004) also shows that analyzing a two-sided market as if it was a one-sided market may lead to some policy errors. Different from him, however, this paper identifies some new issues raised by switching costs in two-sided markets that have not been discussed previously.

[19] Note that the concept of multi-homing is not compatible with switching costs in the current framework. I use two examples to illustrate. First, think of the smartphone market. If the option to multi-home means consumers are able to use both iPhone and Android systems, then it is not reasonable to impose an additional learning

model lies in the market share of side-B consumers, which can be described as follows. In period t, $t \in \{1,2\}$, a side-B consumer located at $\theta^B_{0,t}$ is indifferent between buying and not buying from platform 0 if

$$v_B + e_B n^A_{0,t} - \theta^B_{0,t} - p^B_{0,t} = 0,$$

which can be simplified to

$$\theta^B_{0,t} = v_B + e_B n^A_{0,t} - p^B_{0,t}.$$

Similarly, a side-B consumer located at $\theta^B_{1,t}$ is indifferent between buying and not buying from platform 1 if

$$v_B + e_B(1 - n^A_{0,t}) - (1 - \theta^B_{1,t}) - p^B_{1,t} = 0,$$

which can be simplified to

$$\theta^B_{1,t} = v_B + e_B(1 - n^A_{0,t}) - p^B_{1,t}.$$

We solve the game by backward induction as before. Consider the symmetric equilibrium. Appendix F proves the existence of it. We can then derive the equilibrium prices.

Proposition 8. *In the multi-homing model, with all consumers and both platforms equally rational, $\delta_i = \delta_F = \delta > 0$ and $\alpha_i = 0$; independent preferences, $\mu_i = 0$; and symmetric externalities, $e_i = e > 0$, $i \in \{A, B\}$,*

i. For the single-homing consumers, if externalities are weak, the first-period price $p^A_{0,1}$ is U-shape in switching costs s_A. If externalities are strong, the first-period price $p^A_{0,1}$ is decreasing in s_A.

ii. If the market is fully covered, then first-period prices tend to be higher on the multi-homing side and lower on the single-homing side with respect to the single-homing model in Section 3.6.

Proof. See Appendix F. □

Part (i) implies that for single-homing consumers stronger externalities make it more likely that first-period equilibrium prices decrease with switching costs, which is consistent with Proposition 5 in the single-homing model. As for multi-homing consumers, both switching costs and the degree of sophistication do not affect the price paid by them because each period's choice is independent. This case and the previous case of asymmetric sides have similar intuition because $s_B, \mu_B = 0$. Part (ii) is different from results in the single-homing model. Since side B multi-homes, there is no competition between the two platforms to attract this group. Compared with the case of asymmetric sides, the higher first-period price faced

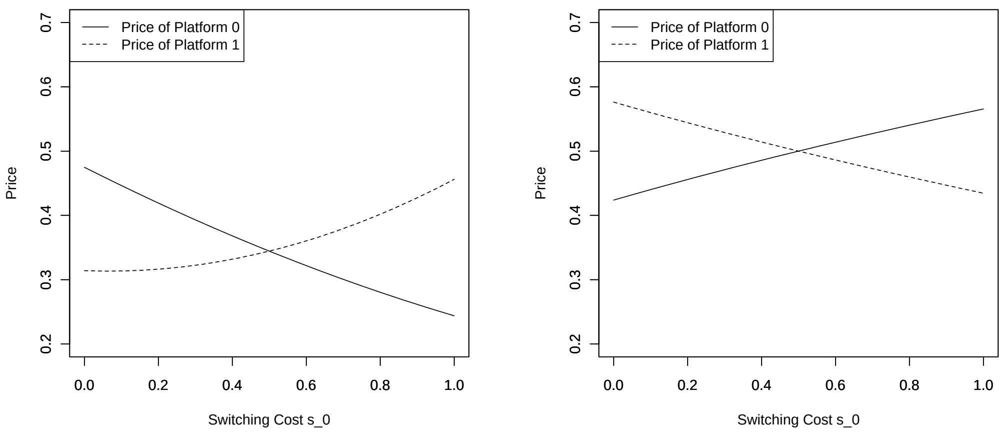
cost on them if they switch platform. Another example is the media market. If multi-homing means that advertisers are free to put ads on either or both platforms, then it does not make sense to impose an additional switching cost on these advertisers. One may argue that we can distinguish between learning switching costs (incurred only at a switch to a new supplier) and transactional switching costs (incurred at every switch), as in Nilssen (1992), but switching costs are not relevant on the multi-homing side because learning costs and transaction costs are equivalent in a two-period model. This also explains why it is not useful to consider the case in which both sides multi-home.

by the multi-homing side is a consequence of each platform having monopoly power over this side, and the large revenue is used in the form of lower first-period price to convince the single-homing side to join the platform.

Before, in the single-homing model, switching costs do not affect the first-period welfare, but lowers the second-period welfare. However, in the multi-homing model switching costs affect first-period welfare through participation, which is, in turn, determined by the price. In the second period, switching cost has no effect on price because platforms have an equal share of the market, and their incentives to exploit old customers offset their incentives to poach new customers. If switching costs reduce first-period price (see (i) of Proposition 8, especially when externalities are strong), then switching costs may increase welfare.[20] This is because lower price induces more consumers to multi-home, and more multi-homing consumers increases the utility of single-homing consumers.

5.2 Asymmetric Platforms

Let us now consider asymmetric platforms. The cost of switching from platform 0 to 1, denoted s_0, is different from the cost of switching from platform 1 to 0, denoted s_1. As an example, some say "iPhones are more expensive than most Samsung smartphones."[21] Can we attribute the difference in the pricing of devices between Apple and Samsung to the fact that Apple has successfully built an ecosystem that makes users hard to switch? To address this question, consider two groups of consumers who are asymmetric in the sense that only consumers on side A incur switching costs in the second period. For simplicity, assume that all consumers single-home. Consider a numerical example where $\delta_A = \delta_B = \delta_F = 0.8$, $\mu_A = \mu_B = 0$, $e_A = e_B = 0.5$, $s_1 = 0.5$, and $s_0 \in [0, 1]$.



(a) First-period Prices (b) Second-period Prices

Figure 1: Equilibrium Pricing with Asymmetric Platforms.

[20]If there is quality choice as in Anderson et al. (2013), then welfare effects are less clear-cut: platform's investment in quality may change depending on whether multi-homing is allowed.

[21]NBC News, "Apple is biggest US phone seller for first time," 1 February 2013, by Peter Svensson. `http://www.nbcnews.com/technology/apple-biggest-us-phone-seller-first-time-1B8210244`

The results are illustrated in Figure 1. Panel (a) presents the first-period pricing, and panel (b) shows the second-period pricing as functions of switching costs s_0. Pricing of platform 0 is shown with a solid line, and that of platform 1 is drawn as a dotted line. It is shown that if $s_0 < s_1$, platform 1 charges a lower price than platform 0 in the first period, but a higher price in the second period. The intuitive reason is that since platform 1 is relatively more expensive to switch away from in the second period, it is willing to charge a lower price in the first period in order to acquire more customers whom it can exploit later. On the contrary, if $s_0 > s_1$, platform 1, knowing that consumers will easily switch away tomorrow, will raise its price today. This result holds as long as externalities are not too strong.[22]

6 Conclusion

This paper has characterized the equilibrium pricing strategy of platforms competing in two-sided markets with switching costs. The main contribution is that it has provided a useful model for generalizing arguments already used in the switching-cost and the two-sided market literature, and for extending beyond traditional results. In line with earlier research, there are some conditions under which switching costs reduce first-period prices but increase second-period prices (à la Klemperer); and prices tend to be lower on the side that exerts a stronger externalities (à la Armstrong). However, this model develops the idea further by proving that in a dynamic two-sided market - as opposed to a merely static one - under weak externalities, switching costs soften price competition in the first period if consumers are significantly more patient than the platforms; under strong externalities, switching costs always make the market more competitive. In terms of consumer heterogeneity, the presence of more loyal and naive consumers on one side intensifies price competition in the first period on this side.

The analysis could be extended in a number of different directions. First, this paper has taken switching costs as an exogenous feature of the market. Future research could consider endogenous switching costs. Second, this paper has focused on a two-period model, and it would be useful to understand the extent to which the results carry over to a multi-period model. Finally, this paper has explored heterogeneity such as loyalty and naivety, but one can think of other forms of heterogeneity across consumers. For example, within-group switching costs may be different between the technologically advanced customers and the less advanced ones. Within-group externalities may also be different: youngsters use applications more heavily, and therefore care more about network externalities than their older counterparts, many of whom only use their smartphones for phone calls and text messages. However, including these forms of heterogeneity will complicate the analysis considerably. The current model captures a lot of ingredients in reality, yet is sufficiently tractable to allow for a complete characterization of the equilibrium. This seems to be a reasonable first step to extend a literature that has not fully explored the implications of consumer heterogeneity.

[22] For large externalities ($e \to 1$), symmetric equilibrium does not exist because there is coordination problem. Given that externalities are so strong, all consumers might want to join one platform only.

Appendices

A Second Period Equilibrium

Solving for $n_{0,2}^A$ and $n_{0,2}^B$ in Equation (2) simultaneously, we obtain the second-period market shares as follows:

$$n_{0,2}^i = \frac{\gamma + \beta_i + (1-\mu_i)(p_{1,2}^i - p_{0,2}^i) + e_i(1-\mu_i)(1-\mu_j)(p_{1,2}^j - p_{0,2}^j)}{2\gamma},$$

where

$$\begin{aligned}
\gamma =& 1 - (1-\mu_A)(1-\mu_B)e_A e_B, \\
\beta_i =& (2n_{0,1}^i - 1)(\mu_i + (1-\mu_i)s_i) + (2n_{0,1}^j - 1)(1-\mu_i)e_i(\mu_j + (1-\mu_j)s_j).
\end{aligned}$$

Because $e_i < 1$, we have $\gamma > 0$.

Substituting the market shares into the profit function in Equation (1), and differentiating it with respect to the prices, we obtain the following equations.

$$\begin{aligned}
\frac{\partial \pi_{0,2}}{\partial p_{0,2}^i} &= n_{0,2}^i - \frac{p_{0,2}^i}{2\gamma}(1-\mu_i) - \frac{p_{0,2}^j}{2\gamma}e_j(1-\mu_i)(1-\mu_j), \\
\frac{\partial \pi_{1,2}}{\partial p_{1,2}^i} &= 1 - n_{0,2}^i - \frac{p_{1,2}^i}{2\gamma}(1-\mu_i) - \frac{p_{1,2}^j}{2\gamma}e_j(1-\mu_i)(1-\mu_j).
\end{aligned}$$

Solving the system of first-order conditions, one finds the following second-period equilibrium prices.

$$\begin{aligned}
p_{0,2}^i &= \frac{1 - e_j(1-\mu_i)}{1-\mu_i} + \frac{\eta_i\lambda_i + \epsilon_i\lambda_j}{(1-\mu_i)\Delta}, \\
p_{1,2}^i &= \frac{1 - e_j(1-\mu_i)}{1-\mu_i} - \frac{\eta_i\lambda_i + \epsilon_i\lambda_j}{(1-\mu_i)\Delta}.
\end{aligned} \tag{A.1}$$

where

$$\begin{aligned}
\Delta &= 9 - (1-\mu_A)(1-\mu_B)(e_A + 2e_B)(e_B + 2e_A) > 0, \\
\lambda_i &= (2n_{0,1}^i - 1)(\mu_i + (1-\mu_i)s_i), \\
\eta_i &= 3 - e_j(e_j + 2e_i)(1-\mu_i)(1-\mu_j) > 0, \\
\epsilon_i &= (1-\mu_i)(e_i - e_j).
\end{aligned}$$

A.1 Proof of Proposition 1

Differentiate Equation (A.1) with respect to s_i, we have

$$\begin{aligned}
\operatorname{sign}\frac{\partial p_{0,2}^i}{\partial s_i} =& \operatorname{sign}(n_{0,1}^i - \frac{1}{2}), \\
\frac{\partial p_{0,2}^i}{\partial s_i} =& -\frac{\partial p_{1,2}^i}{\partial s_i}.
\end{aligned}$$

A.2 Proof of Proposition 2

Differentiate Equation (A.1) with respect to s_j, we have

$$\begin{aligned}
\operatorname{sign}\frac{\partial p_{0,2}^i}{\partial s_j} &= \operatorname{sign}(e_i - e_j)(n_{0,1}^j - \frac{1}{2}), \\
\frac{\partial p_{0,2}^i}{\partial s_j} &= -\frac{\partial p_{1,2}^i}{\partial s_j}.
\end{aligned}$$

A.3 Proof of Proposition 3

The second-period profit of platform 0 is

$$\begin{aligned}
\pi_{0,2} &= p_{0,2}^A n_{0,2}^A + p_{0,2}^B n_{0,2}^B \\
&= \left[\frac{1 - e_B(1-\mu_A)}{1-\mu_A} + \frac{\eta_A\lambda_A + \epsilon_A\lambda_B}{(1-\mu_A)\Delta}\right]\left[\frac{1}{2} + \frac{3\lambda_A + (1-\mu_A)(e_A + 2e_B)\lambda_B}{2\Delta}\right] \\
&\quad + \left[\frac{1 - e_A(1-\mu_B)}{1-\mu_B} + \frac{\eta_B\lambda_B + \epsilon_B\lambda_A}{(1-\mu_B)\Delta}\right]\left[\frac{1}{2} + \frac{3\lambda_B + (1-\mu_B)(e_B + 2e_A)\lambda_A}{2\Delta}\right].
\end{aligned}$$

The first-order conditions with respect to s_A and s_B are

$$\frac{\partial \pi_{0,2}}{\partial s_i} = \frac{\partial \pi_{0,2}}{\partial \lambda_i}(2n_{0,1}^i - 1)(1-\mu_i),$$

where

$$\begin{aligned}
\frac{\partial \pi_{0,2}}{\partial \lambda_i} =& \frac{\eta_i}{(1-\mu_i)\Delta}\left[\frac{1}{2} + \frac{3\lambda_i + (1-\mu_i)(e_i + 2e_j)\lambda_j}{2\Delta}\right] \\
&+ \frac{3}{2\Delta}\left[\frac{1 - e_j(1-\mu_i)}{1-\mu_i} + \frac{\eta_i\lambda_i + \epsilon_i\lambda_j}{(1-\mu_i)\Delta}\right] \\
&+ \frac{\epsilon_j}{(1-\mu_j)\Delta}\left[\frac{1}{2} + \frac{3\lambda_j + (1-\mu_j)(e_j + 2e_i)\lambda_i}{2\Delta}\right] \\
&+ \frac{(1-\mu_j)(e_j + 2e_i)}{2\Delta}\left[\frac{1 - e_i(1-\mu_j)}{1-\mu_j} + \frac{\eta_j\lambda_j + \epsilon_j\lambda_i}{(1-\mu_j)\Delta}\right].
\end{aligned}$$

Therefore,

$$\operatorname{sign}\frac{\partial \pi_{0,2}}{\partial s_i} = \operatorname{sign}(n_{0,1}^i - \frac{1}{2})$$

if

$$\frac{\partial \pi_{0,2}}{\partial \lambda_i} > 0.$$

For $\partial\pi_{0,2}/\partial\lambda_i > 0$, we need $n_{0,1}^A$ and $n_{0,1}^B$ not too close to zero, as well as e_A and e_B are not too different.

B First Period Equilibrium

The indifferent rational consumer is given by

$$\theta_R^i = \frac{1}{2} + \frac{e_i(2n_{0,1}^j - 1) + p_{1,1}^i - p_{0,1}^i + \delta_i(\mu_i + (1-\mu_i)s_i)\frac{[(1-\mu_i)(e_i+2e_j)\lambda_j + (3-\Delta)\lambda_i]}{(1-\mu_i)\Delta}}{2(1+\delta_i\mu_i)}.$$

Substitute θ^i_N and θ^i_R into Equation (3), and solve simultaneously for $n^A_{0,1}$ and $n^B_{0,1}$:

$$n^i_{0,1} = \frac{1}{2} + \frac{e_i(1-\kappa_j)(p^i_{1,1}-p^i_{0,1}) + \tau_j(e_i\tau_i+\sigma_i)(p^j_{1,1}-p^j_{0,1})}{2[(1-\kappa_i)(1-\kappa_j)-(e_i\tau_i+\sigma_i)(e_j\tau_j+\sigma_j)]},$$

where

$$\begin{aligned}
\tau_i =& \alpha_i + \frac{1-\alpha_i}{1+\delta_i\mu_i}, \\
\kappa_i =& \frac{\delta_i(\mu_i+(1-\mu_i)s_i)(3-\Delta)(1-\alpha_i)(\mu_i+(1-\mu_i)s_i)}{(1-\mu_i)\Delta(1+\delta_i\mu_i)}, \\
\sigma_i =& \frac{\delta_i(\mu_i+(1-\mu_i)s_i)(e_i+2e_j)(1-\alpha_i)(\mu_j+(1-\mu_j)s_j)}{\Delta(1+\delta_i\mu_i)}.
\end{aligned}$$

The expected profit of platform 0 is

$$\pi_0 = p^A_{0,1}n^A_{0,1} + p^B_{0,1}n^B_{0,1} + \delta_F\pi_{0,2}.$$

The first-order conditions for maximizing π_0 with respect to $p^A_{0,1}$ and $p^B_{0,1}$ are given as follows.

$$\frac{\partial\pi_0}{\partial p^i_{0,1}} = n^i_{0,1} - p^i_{0,1}\frac{\tau_i(1-\kappa_j)}{2\varphi} - p^j_{0,1}\frac{\tau_i(e_j\tau_j+\sigma_j)}{2\varphi} + \delta_F\left[\frac{\partial\pi_{0,2}}{\partial n^i_{0,1}}\frac{\partial n^i_{0,1}}{\partial p^i_{0,1}} + \frac{\partial\pi_{0,2}}{\partial n^j_{0,1}}\frac{\partial n^j_{0,1}}{\partial p^i_{0,1}}\right]$$

where

$$\begin{aligned}
\varphi =& (1-\kappa_i)(1-\kappa_j) - (e_i\tau_i+\sigma_i)(e_j\tau_j+\sigma_j), \\
\frac{\partial\pi_{0,2}}{\partial n^i_{0,1}} =& \left[\frac{6}{(1-\mu_i)\Delta} + \frac{(e_i-e_j)-(e_i+e_j)(e_j+2e_i)(1-\mu_j)}{\Delta}\right](\mu_i+(1-\mu_i)s_i) \stackrel{\text{def}}{=} \xi_i.
\end{aligned}$$

Similarly, there are two first-order conditions for platform 1.

I focus on the platform-symmetric equilibrium, where $p^A_{0,1} = p^A_{1,1} = p^A$ and $p^B_{0,1} = p^B_{1,1} = p^B$. I derive the sufficient condition for the existence of such symmetric equilibrium, which requires that platform k's profit is concave in its prices. The concavity condition is as follows.

$$1-\kappa_A > e_A\tau_A + \sigma_A > 0; \quad 1-\kappa_B > e_B\tau_B+\sigma_B > 0. \tag{B.1}$$

In addition to Equation (B.1), to ensure that the platform does not deviate from the equilibrium price, we need the following condition:

$$v_i + \frac{1}{2}e_i - \frac{1}{2} > \frac{1}{1-\mu_i} - e_i > (v_i + \frac{1}{2}e_i - \frac{1}{2})\mu_i, \quad i \in \{A, B\}. \tag{B.2}$$

The first inequality means that we need v_i to be big enough such that the market is covered. The second inequality means that we need μ_i to be small enough and v_i to be big, but not too big, in order to guarantee that the platform does not deviate to serve only loyal consumers in the second period. For example, Equations (B.1) and (B.2) are satisfied when α_i is big and/or $\mu_i = 0$ is small.[23]

[23]When $\alpha_i = 1$, we obtain the same existence condition for a symmetric equilibrium as in Armstrong (2006). I show that the equilibrium exists for a wider range of parameters.

Under symmetric equilibrium, the first-period equilibrium prices for side A and side B are given respectively by

$$p^A_{0,1} = \frac{1-\kappa_A}{\tau_A} - \frac{\sigma_B}{\tau_B} - e_B - \delta_F \xi_A; \quad p^B_{0,1} = \frac{1-\kappa_B}{\tau_B} - \frac{\sigma_A}{\tau_A} - e_A - \delta_F \xi_B, \tag{B.3}$$

and the second-period equilibrium prices are given by

$$p^A_{0,2} = \frac{1-e_B(1-\mu_A)}{1-\mu_A}; \quad p^B_{0,2} = \frac{1-e_A(1-\mu_B)}{1-\mu_B}.$$

C Proof of Proposition 5

If $\delta_A = \delta_B = \delta_F = \delta > 0$, $\alpha_A = \alpha_B = 0$, $\mu_A = \mu_B = 0$, and $e_A = e_B = e > 0$, Equation (B.3) becomes

$$p^i_{0,1} = 1 - e + \frac{\delta}{3(1-e^2)} \left[(2-3e^2)s_i^2 - 2(1-e^2)s_i - e s_i s_j\right].$$

Differentiating $p^i_{0,1}$ with respect to s_i, we obtain

$$\begin{aligned}
\frac{\partial p^i_{0,1}}{\partial s_i} &= \frac{\delta}{3(1-e^2)} \left[2(2-3e^2)s_i - 2(1-e^2) - e s_j\right], \\
\frac{\partial^2 p^i_{0,1}}{\partial s_i^2} &= \frac{2\delta(2-3e^2)}{3(1-e^2)} \begin{cases} > 0 & \text{if } e < \sqrt{2/3}, \\ < 0 & \text{if } e \geq \sqrt{2/3}, \end{cases} \\
\frac{\partial p^i_{0,1}}{\partial s_i}\Big|_{s_i=0} &= \frac{\delta}{3(1-e^2)} \left[-2(1-e^2) - e s_j\right] < 0.
\end{aligned}$$

Therefore, $p^i_{0,1}$ is U-shape in s_i if $e < \sqrt{2/3}$, and decreasing in s_i if $e \geq \sqrt{2/3}$.

Differentiating $p^i_{0,1}$ with respect to s_j, we get

$$\frac{\partial p^i_{0,1}}{\partial s_j} = -\frac{\delta e s_i}{3(1-e^2)} < 0.$$

Therefore, $p^i_{0,1}$ is decreasing in s_j.

D Proof of Proposition 6

If $\delta_A = \delta_B = 0$, $\alpha_A = \alpha_B = 1$, and $\mu_A = \mu_B = 0$, Equation (B.3) becomes

$$p^i_{0,1} = 1 - \delta_F \left[\frac{6 + e_i - e_j - (e_i + e_j)(e_j + 2e_i)}{\Delta}\right] s_i - e_j.$$

Differentiating it with respect to s_i, we obtain

$$\frac{\partial p^i_{0,1}}{\partial s_i} < 0.$$

E Proof of Proposition 7

Differentiating Equation (B.3) with respect to α_A, α_B and δ_F, we obtain the following:

$$\frac{\partial p^i_{0,1}}{\partial \alpha_i} \begin{cases} \leq 0, & \text{if } \mu_i \to 1 \text{ or } e_i, e_j \to 0, \\ > 0, & \text{if } \mu_i \to 0 \text{ and } e_i, e_j \to 1, \end{cases}$$

since

$$\frac{\partial p^i_{0,1}}{\partial \alpha_i} > 0 \ \text{ if } \ \frac{\mu_i + 2\mu_i(1-\mu_i)s_i + (1-\mu_i)^2 s_i^2}{\mu_i^2 + 3\mu_i(1-\mu_i)s_i + (1-\mu_i)^2 s_i^2} > \frac{\Delta}{3}.$$

$$\frac{\partial p^i_{0,1}}{\partial \alpha_j} \geq 0.$$

$$\frac{\partial p^i_{0,1}}{\partial \delta_F} = -\xi_i \leq 0.$$

F Proof of Proposition 8

The first-order conditions of π_k, $k \in \{0,1\}$, with respect to $p^A_{0,1}$ and $p^B_{0,1}$ are, respectively,

$$n^A_{k,1} - \frac{1}{2\omega} p^A_{k,1} - \frac{e}{2\omega} p^B_{k,1} - \frac{\delta}{2\omega} \frac{\partial \pi_{k,2}}{\partial n^A_{0,1}} = 0,$$
$$n^B_{k,1} - (1 + \frac{e^2}{2\omega}) p^B_{k,1} - \frac{e}{2\omega} p^A_{k,1} - \frac{\delta e}{2\omega} \frac{\partial \pi_{k,2}}{\partial n^A_{0,1}} = 0,$$

where

$$\omega = 1 - e^2 - \frac{\delta s_A^2 (e^2 - 2\gamma)}{3\gamma}.$$

Using similar proof as in the single-homing model, the symmetric equilibrium exists in the multi-homing model. The existence conditions are as follows. First, platform k's profit is concave in its prices if $\omega \geq 0$, which means that δ, s_A and e are not too big.

Second, we need to ensure that the platform does not deviate to sell only to loyal consumers on side A.

$$v_A + e(\frac{v_B}{2} + \frac{e}{2}) - \frac{1}{2} > 1 - (1-\mu_A)e^2 - \frac{e v_B}{2} > \left[v_A + e(\frac{v_B}{2} + \frac{e}{2}) - \frac{1}{2} \right] \mu_A,$$

or equivalently, μ_A is small, and v_B is big, but not too big.

The first-period equilibrium prices are as follows.

$$p^A_{0,1} = 1 - e^2 - \frac{\delta(3e^2 - 2)s_A^2}{3(1-e^2)} - \frac{2\delta s_A}{3} - \frac{v_B e}{2},$$
$$p^B_{0,1} = \frac{v_B}{2}.$$

For part (i), differentiate $p_{0,1}^A$ with respect to s_A.

$$\begin{aligned}
\frac{\partial p_{0,1}^A}{\partial s_A} &= -\frac{2\delta}{3} - \frac{2\delta(3e^2-2)s_A}{3(1-e^2)}, \\
\frac{\partial^2 p_{0,1}^A}{\partial s_A^2} &= -\frac{2\delta(3e^2-2)}{3(1-e^2)} \begin{cases} > 0 & \text{if } e < \sqrt{2/3}, \\ < 0 & \text{if } e \geq \sqrt{2/3}, \end{cases} \\
\frac{\partial p_{0,1}^A}{\partial s_A}|_{s_A=0} &= -\frac{2\delta}{3} < 0.
\end{aligned}$$

Therefore, $p_{0,1}^A$ is U-shape in s_A if $e < \sqrt{2/3}$, and decreasing in s_A if $e \geq \sqrt{2/3}$.

For part (ii), we compare the first-period prices paid by consumers who bear switching costs (side-A) and those who do not (side-B) in the multi-homing model (denoted mh) with that in the single-homing model in Section 3.6 (denoted sh).

For side-A,

$$p_{mh}^A < p_{sh}^A \text{ if } e + \tfrac{v_B}{2} > 1.$$

For side-B,

$$p_{mh}^B > p_{sh}^B \text{ if } e + \tfrac{v_B}{2} > 1.$$

References

[1] Simon Anderson, Øystein Foros, and Hans Jarle Kind. Competition for Advertisers in Media Markets. In *Fourteenth CEPR/JIE Conference on Applied Industrial Organization*, 2013.

[2] Mark Armstrong. Competition in two-sided markets. *RAND Journal of Economics*, 37(3):668–691, 2006.

[3] Gary Biglaiser and Jacques Crémer. Switching Costs and Network Effects in Competition Policy. *Recent advances in the analysis of competition policy and regulation*, 2014, forthcoming.

[4] Gary Biglaiser, Jacques Crémer, and Gergely Dobos. The value of switching costs. *Journal of Economic Theory*, 148(3):935–952, 2013.

[5] Severin Borenstein, Jeffrey MacKie-Mason, and Janet Netz. Exercising Market Power in Proprietary Aftermarkets. *Journal of Economics and Management Strategy*, 9(2):157–188, 2000.

[6] Bernard Caillaud and Bruno Jullien. Chicken & egg: competition among intermediation service providers. *RAND Journal of Economics*, 34(2):309–328, 2003.

[7] Yongmin Chen. Paying Customers to Switch. *Journal of Economics & Management Strategy*, 6(4):877–897, 1997.

[8] Liran Einav and Paulo Somaini. A Model of Market Power in Customer Markets. *Journal of Industrial Economics*, 2013, forthcoming.

[9] Joseph Farrell and Paul Klemperer. Coordination and Lock-in: Competition with Switching Costs and Network Effects. In Mark Armstrong and Rob Porter, editors, *Handbook of Industrial Organization*, volume 3, chapter 31, pages 1967–2072. North-Holland, 2007.

[10] Jean Gabszewicz, Lynne Pepall, and Jacques-François Thisse. Sequential Entry with Brand Loyalty Caused by Consumer Learning-by-Using. *Journal of Industrial Economics*, 40(4):397–416, 1992.

[11] Paul Klemperer. Markets with Consumer Switching Costs. *Quarterly Journal of Economics*, 102(2):375–394, 1987a.

[12] Paul Klemperer. The competitiveness of markets with switching costs. *RAND Journal of Economics*, 18(1):138–150, 1987b.

[13] Paul Klemperer. Competition when Consumers have Switching Costs: An Overview with Applications to Industrial Organization, Macroeconomics, and International Trade. *Review of Economic Studies*, 62:515–539, 1995.

[14] Tore Nilssen. Two Kinds of Consumer Switching Costs. *RAND Journal of Economics*, 23(4):579–589, 1992.

[15] Office of Fair Trading. Switching costs. Report of the UK government Office of Fair Trading, 2003.

[16] Andrew Rhodes. Re-examining the Effects of Switching Costs. Toulouse School of Economics Working Paper, 2013.

[17] Jean-Charles Rochet and Jean Tirole. Platform Competition in Two-Sided Markets. *Journal of the European Economic Association*, 1(4):990–1029, 2003.

[18] Jean-Charles Rochet and Jean Tirole. Two-sided markets: a progress report. *RAND Journal of Economics*, 37(3):645–667, 2006.

[19] Marc Rysman. The Economics of Two-sided Markets. *Journal of Economic Perspective*, 23(3):125–143, 2009.

[20] Su Su and Na Zeng. The Analysis of Two Period Equilibrium of Two-sided Competing Platforms. In *Wireless Communications, Networking and Mobile Computing, 2008. WiCOM '08. 4th International Conference on Communication, Networking & Broadcasting; Computing & Processing (Hardware/Software)*, 2008.

[21] Curtis Taylor. Supplier surfing: competition and consumer behavior in subscription markets. *RAND Journal of Economics*, 34(2):223–246, 2003.

[22] Christian von Weizsäcker. The Costs of Substitution. *Econometrica*, 52(5):1085–1116, 1984.

[23] Julian Wright. One-sided Logic in Two-sided Markets. *Review of Network Economics*, 3(1):44–64, 2004.