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Abstract

This paper investigates firms' decisions to reimburse consumers' switching costs in network industries. Prior literature finds that switching costs incentivize firms to harvest their locked-in consumers rather than price aggressively for market dominance, resulting in a lower market concentration. Using a dynamic duopoly model, we show that this result is reversed if firms have the option to reimburse consumers' switching costs. In that case the larger firm offers a bigger reimbursement to switching consumers than the smaller firm does, as an additional instrument to propel itself to market dominance. Consequently, an increase in switching cost increases market concentration. Compared to the case without reimbursements, allowing firms the option to reimburse results in greater consumer welfare despite having a much higher market concentration. Consumers' benefits from a larger network and switching cost reimbursement outweigh the higher price charged by a dominant firm.

Keywords: network goods, price discrimination, reimbursement, switching costs.

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1 Introduction

Some of the largest and most important markets in the economy are characterized by switching costs. For instance, switching health insurance plans often requires consumers to switch primary care providers as well.¹ Credit markets are also characterized by switching costs, where switching lenders means clearing old debts and closing old accounts in order to open new accounts (Stango, 2002) and losing relationship-based benefits such as easier access to credit and lower interest rates (Barone et al., 2011). Similar stories can be told with respect to the television industry (Shcherbakov, 2016) and the telephone/wireless industry (Viard, 2007; Cullen and Shcherbakov, 2010; Park, 2011), among others.

Firms competing in such markets have the incentive to practice third-degree price discrimination by offering different prices to first time buyers, repeat buyers and competitors' consumers. In markets characterized by switching costs, the ability to practice price discrimination allows firms to decrease the real cost of switching. For example, Verizon Wireless recently announced that it would cover up to \$650 in switching costs.² Alike announcements were made by T-Mobile and Sprint.³ In consumer financial markets, a quick internet search will yield many companies that offer new consumers zero percent interest on balance transfers on credit cards as well as various other promotional banking offers.⁴ In this paper, we develop an infinite horizon duopoly model with network effects and an outside option where firms compete in prices and choose what proportion of its competitors' consumers'

¹Strombom et al. (2002) empirically study switching costs in the health industry with respect to age, health status and employment tenure.

²<http://www.verizonwireless.com/landingpages/switch-and-save/>, accessed March 18, 2016.

³<http://newsroom.sprint.com/news-releases/sprint-will-reimburse-all-your-costs-to-switch-join-sprints-56-million-customers-today.htm>, accessed 19 March 2016 and <http://www.t-mobile.com/offer/no-early-termination-fees-info.html>, accessed 19 March 2016.

⁴<http://www.moneycrashers.com/best-new-bank-account-promotions-offers/>, accessed 25 September 2016.

switching costs to cover. We use the model to understand when a firm will have the incentive to reimburse its competitors' switching costs.

The firms dynamically optimize across an infinite horizon, making both a pricing and a reimbursement decision at each time period. Price discrimination occurs only through the reimbursement channel. In each time period, each firm's installed base depreciates with some probability, which can be interpreted as product death (or alternatively, a consumer's subscription expiring). Those consumers whose product dies are back on the market and choose to buy the good that maximizes current utility, be it from one of the firms or the outside option.⁵ Consumers face a switching cost only if their most recent purchase was from the competing firm. Those who choose the outside option and those who join the market from the outside option do not face a switching cost.

To illustrate the model setup, consider an example from the software industry. Suppose that there are two sellers of computer-aided design (CAD) software, which many engineers use to design structures/models. The outside option is a pen and graph paper. Each seller offers subscriptions of various lengths to its product. For example, the current purchase price for a one-year subscription AutoCAD by Autodesk is \$1,400. Switching platforms implies two potential switching costs: learning to use the new software (Sacks, 2015) and the time required to transfer and convert projects designed using the previous platform to the new platform. When a consumer's subscription expires, she must decide whether to continue with the current CAD software, switch to a competing CAD software or abandon CAD software altogether and select the outside option. The firm is able to mitigate both types of costs by offering new consumers resources such as free training.⁶

⁵That is to say, consumers are myopic best responders.

⁶Alternatively, the firms can use compatibility as in Chen (2015).

This setup allows us to use numerical methods to calculate a Markov perfect equilibrium. We use this equilibrium to investigate how the firms' pricing and reimbursement decisions influence the long run industry dynamics, exploring the firms' equilibrium pricing and reimbursement strategies in order to characterize the set of states in which firms choose to reimburse switching costs and to explore how that set depends on the magnitude of switching costs as well as the strength of the network effect. Two particular types of equilibria emerge. The first type is a tipping equilibrium, in which one firm dominates the market (Herfindahl-Hirschman Index above 0.7). The second type is a splintered equilibrium, in which the firms split the market (Herfindahl-Hirschman Index of approximately 0.5).

We build our analysis by studying two regimes. In the first regime, the firms do not have the ability to reimburse their competitor's switching cost. We call this regime the no reimbursement (NR) regime and it serves as a benchmark that allows us to consider how competition is affected by the reimbursement decision. In the second regime, each firm simultaneously chooses its price and the proportion of its competitor's switching cost it wishes to reimburse. We call this regime the endogenous reimbursement (ER) regime.

Under the NR regime, we find that switching costs tend to reduce market concentration, sometimes dramatically. This result is not new and is consistent with the existing literature for both non-network goods (Beggs and Klemperer, 1992; Chen and Rosenthal, 1996; Taylor, 2003) and network goods (Chen, 2016). In other words, an increase in the switching cost can transition the equilibrium from a tipping equilibrium to a splintered equilibrium. It follows that if switching costs are high, then firms are unable to effectively utilize the much discussed bargain-then-ripoff strategy (Farrell and Klemperer, 2007) as the price reduction necessary to stimulate switching is prohibitively large. Instead of a bargain-then-ripoff strategy, firms soften their com-

petition and charge higher prices (the “ripoff” phase) in order to harvest surpluses from locked-in consumers.

Under the ER regime, we find that the larger firm can utilize the reimbursement of switching costs to counteract the effect of the switching cost from the benchmark. We show that even with strong switching cost, the larger firm is able to achieve market dominance through the reimbursement channel, and the economy remains in a tipping equilibrium.

If the initial market shares are nearly symmetric, then the firms play what resembles a bargain-then-ripoff strategy. Not only are prices below marginal cost when the firms have similar market shares, but the firms are also reimbursing a small portion of the switching costs, further enhancing the “bargain” phase. As one firm begins to gain an advantage, prices rise above marginal cost. The larger firm reimburses a greater share of the switching cost than the smaller firm, which is still positive, thus tempering the “ripoff” phase. If one firm begins with a non-negligible advantage, then prices are initially above marginal cost. Consequently, an increase in the switching cost increases market concentration and the profits of the dominant firm, negating the competition effects of higher switching costs.

It is interesting to note that even though the market is more concentrated and characterized by a higher HHI, consumers receive greater welfare under the ER regime with high switching costs than the NR regime with high switching costs. The positive net consumer surplus between the two regimes is robust across various magnitudes of both the network effect and switching cost. Not only is the consumer surplus always greater in the ER regime than the NR regime, the effective price the consumers face under the ER regime is no larger than the effective price under the NR regime whenever the marginal benefit of the network effect is greater than the magnitude

of the switching cost.⁷ This result is empirically very relevant as it shows that in markets for network goods characterized by switching costs, a higher HHI need not correspond to a less efficient outcome and consumers in fact prefer this outcome over the NR regime, even though market concentration is lower in the latter.

Related Literature. This paper adds to the interrelated literatures on price discrimination and switching costs. The literature on switching costs can be traced back to von Weizsäcker (1984). Shortly thereafter, these markets were examined in Klemperer (1987*a*), Klemperer (1987*b*), and Klemperer (1987*c*). Since then, much headway has been made. A thorough summary through 2007 is given in Farrell and Klemperer (2007). For a more recent survey, see Villas-Boas (2015).

Chen (1997) and Shaffer and Zhang (2000) are among the first to formally study switching cost reimbursements. Using a two period model, Chen (1997) finds that firms play a “bargain-then-ripoff” strategy, where the prices in the first period are below marginal cost while prices in the second period are above marginal cost. When engaging in discriminatory pricing, firms are worse off and consumers are not necessarily better off, leading to deadweight losses. Moreover the discriminatory price is not a function of the firm’s market share. In the current study, we find that by extending the time frame to an infinite horizon, both the pricing and reimbursement decisions depend explicitly on the firm’s market share.

Shaffer and Zhang (2000) use a one-shot model to show that when demand is symmetric, a firm charges a lower price to its rival’s consumers (paying to switch).⁸ However, when demand is asymmetric, a firm charges a lower price to its own consumers (paying to stay). In the current study, we are able to capture firms’ long-run

⁷The effective price is defined as the probability-weighted real price the average consumer faces, taking into account switching cost and reimbursement of such cost. A formal definition is provided in Section 3.

⁸Fudenberg and Tirole (2000) refer to this strategy as consumer poaching.

considerations using a dynamic structure, where pricing and reimbursement decisions today influence not only the firms' current market shares, but their long run shares as well. These dynamic considerations can, and often do, yield distinct results. In contrast to Shaffer and Zhang (2000), we find that in the long run, when the firms have asymmetric market shares (the splintered equilibrium), the firm reimburses switching costs, in essence charging a lower price to its rival's customers and a higher price to its own.

More recently, Arie and Grieco (2012), Arie and Grieco (2014), Rhodes (2014) and Fabra and García (2015) incorporated switching costs and price discrimination into dynamic (infinite horizon) models of price competition.⁹ Both Arie and Grieco (2012) and Arie and Grieco (2014) study how switching costs affect the pricing decision when the switching costs are small. Our results are consistent with theirs for small switching costs, and also extend the analysis to cover the spectrum of switching costs.

Rhodes (2014) shows that the effect of switching costs on prices is ambiguous and depends on the magnitude of the switching cost. The paper does not formally consider reimbursement or price discrimination. We also find ambiguity in the pricing decision in the short run, though in our model, whether prices are above or below marginal costs depends on the initial installed base of the firm rather than the magnitude of the switching cost. This relationship follows from our decomposition of the reimbursement decision from the pricing decision.

Fabra and García (2015) incorporated dynamics into a duopoly model of switching costs. Using a continuous time, infinite horizon model, the authors show that in a Markov perfect equilibrium, the dominant firm has the incentive to charge a higher

⁹Farrell and Shapiro (1988) and Farrell and Shapiro (1989) were some of the first dynamic (infinite horizon) models of price competition with switching costs; however, these works abstracted from switching cost reimbursement and price discrimination. The authors find that in the absence of price discrimination, switching costs have pro-entry effects.

price, conceding some of its market share to the smaller firm. However, increases in the switching cost always induce price decreases. In the long run, there is always convergence to a splintered equilibrium. In contrast, we find that the dominant firm is able to maintain its dominance through the reimbursement channel and increases in the switching cost need not induce price decreases.

The remainder of the paper is structured as follows. Section 2 provides a short discussion on switching costs and reimbursements. The formal model is presented in Section 3, followed by the results in Section 4. Section 5 concludes.

2 Switching Costs and Reimbursements: A Discussion

A switching cost is the disutility a consumer receives when transitioning from one good to another. Nilssen (1992) dichotomized the class of switching costs into two categories: learning costs and transaction costs. Transaction costs are incurred every time a consumer switches while learning costs are incurred only on the consumers first use of a product. If the consumer leaves then returns, she does not face this cost again.

Burnham et al. (2003) later developed a switching cost typology that identifies three types of switching costs along a different margin than Nilssen (1992). Firstly switching costs can be procedural, which cost the consumers time and effort. For example, switching banks requires consumers to update their billing information with all creditors. Secondly switching costs can be financial (monetary). For example, many service providers, such as wireless mobile phone providers, charge early termination fees. Thirdly switching costs may be psychological.

The reimbursement of switching costs can occur through two channels: the direct channel where a firm utilizes monetary transfers to reimburse a switching cost or the indirect channel, where the firm reduces the switching cost through alternative means. Wireless carriers reimbursing their competitors' early termination fees are an example of the direct channel. Software developers offering compatibility or training for new users are examples of the indirect channel.

When scholars analyze pricing with switching costs, two effects are often mentioned: the harvesting effect and the investing effect.¹⁰ When a market is characterized by switching costs, a firm can harvest surpluses from its installed base by charging a higher price to its current installed base, knowing that the switching cost will limit consumers from switching to a competitor. Alternatively, a firm can charge a lower price in order to cannibalize its competition and grow its installed base. The lower price decreases current profits, but is an investment in the future. As the installed base grows, it can then harvest its (larger) installed base.

3 Model

This section describes a dynamic duopoly model of network industries in which consumers face switching costs and firms have the option to reimburse such switching costs.

3.1 Supply Side

The model is cast in discrete time with an infinite horizon. There are two firms indexed by $i = 1, 2$, competing in prices that sell a single good to a sequence of buyers with unit demands. Denote by p_i the price for good i . Let $p = (p_1, p_2)$. The

¹⁰See Farrell and Klemperer (2007) for details.

goods are durable and subject to stochastic death. The firms' products are referred to as the *inside goods*. There is also an *outside good* (no purchase), indexed by 0, where p_0 is normalized to zero. Denote the installed base of firm i at time t by $b_i \in \{0, 1, \dots, M\}$, where M is the number of consumers in the market. By extension, $b_1 + b_2 \leq M$ and $b_0 = M - b_1 - b_2$ is the outside good's installed base. The industry state is given by $b = (b_1, b_2)$, where the state space is

$$\Omega = \{(b_1, b_2) \mid 0 \leq b_i \leq M, i = 1, 2; b_1 + b_2 \leq M\}.$$

We assume that it is costly for consumers to switch between inside goods. The cost of switching is assumed to be exogenous and is given by $k > 0$.

In each period, given b , the firms engage in a game, simultaneously deciding what proportion of consumers' switching costs to reimburse and the price to charge consumers. Let $d_i \in [0, 1]$ be the reimbursement choice of firm i , where $d_i = 1$ corresponds to "fully reimburse consumers' switching costs," $d_i = 0$ corresponds to "do not reimburse" and an intermediate value corresponds to "reimburse $d_i \times 100\%$." Let $d = (d_1, d_2)$.

3.2 Demand Side

Demand in each period is derived from a random consumer who purchases one of the three (inside or outside) goods. Denote by $r \in \{0, 1, 2\}$ the good that the consumer is loyal to. A consumer may be loyal to a firm's product because she previously used that product and her product dies so she returns to the market. A second form of loyalty to the firm's product arises because of her relationships with current users. For example, if a consumer is familiar with a particular product because her relatives, friends, or colleagues are users of this product, then she may be loyal to this product

even if she has never purchased from this market before.

Assume that r is distributed according to $Pr(r = j|b) = \frac{b_j}{M}$, $j = 0, 1, 2$, so that a larger installed base implies a larger (expected) demand from loyal consumers. The utility a consumer loyal to good r gets from purchasing good i is

$$u_{ri} = v_i + \mathbf{1}(i \neq 0)\theta g(b_i) - p_i - \mathbf{1}(r \neq 0, i \neq 0, i \neq r)(1 - d_i)k + \epsilon_i, \quad (1)$$

where v_i is the intrinsic product quality, which is fixed over time and common across firms ($v_i = v$, $i = 1, 2$) and ϵ_i is the consumer's idiosyncratic preference shock. When setting prices, ϵ_0 , ϵ_1 , ϵ_2 , and r are unknown to the firms. As the intrinsic quality parameters affect demand only through the expression $v - v_0$, we set $v = 0$ without loss of generality and consider different values for v_0 . The consumer incurs the switching cost if she switches from one inside good to the other, and a portion of her switching cost is reimbursed by the firm if it chooses $d_i > 0$.¹¹ The increasing C^2 function $\theta g(\cdot)$ captures network effects, where $\theta \geq 0$ controls the relative strength of the network effect. We assume the outside good exhibits no network effects. The results reported below are based on linear network effects; that is, $g(b_i) = \frac{b_i}{M}$.¹²

When given the opportunity to reevaluate her purchase, the consumer buys the good that offers the highest current utility. We are thus assuming that consumers make myopic decisions. Such a parsimonious specification of consumers' decision-making allows for rich modeling of firms' prices and industry dynamics.¹³ Allowing consumers to be forward-looking with rational expectations in the presence of both

¹¹A consumer who switches from the outside good to an inside good incurs a start-up cost, which is normalized to zero. Increasing the start-up cost has the effect of lowering the inside good's intrinsic quality relative to that of the outside good.

¹²We have also allowed $g(\cdot)$ to be convex, concave, and S -shaped. The main results are robust to these alternative specifications.

¹³See Ellison (2006) for more information on the use of bounded rationality in the industrial organization literature.

network effects and switching costs is an important but challenging extension of the current work.

We assume that ϵ_i is distributed type I extreme value, independent across products, consumers, and time. Therefore the probability that a consumer who is loyal to good r buys good i is given by the Logit demand function

$$\phi_{ri}(b, d, p) \equiv \frac{\exp(\bar{u}_{ri})}{\sum_{j=0}^2 \exp(\bar{u}_{rj})}, \quad (2)$$

where $\bar{u}_{ri} \equiv u_{ri} - \epsilon_i$ is the deterministic component in u_{ri} .

3.3 Product Depreciation and Transition Probabilities

In each period, each unit of a firm's installed base independently depreciates with exogenous probability $\delta \in [0, 1]$, for example, due to product death. Let $\Delta(x_i|b_i)$ denote the probability that firm i 's installed base depreciates by x_i units. We have

$$\Delta(x_i|b_i) = \binom{b_i}{x_i} \delta^{x_i} (1 - \delta)^{b_i - x_i}, \quad x_i = 0, \dots, b_i, \quad (3)$$

as x_i is distributed binomial with parameters (b_i, δ) . Accordingly, $\mathbb{E}(x_i|b_i) = b_i \delta$. Therefore the expected size of the depreciation to a firm's installed base is proportional to the size of that installed base. When the firms' installed bases depreciate, the number of unattached consumers b_0 increases by the same number as the aggregate depreciation and the total market size is fixed at M .

Let $q_i \in \{0, 1\}$ indicate whether or not firm i makes the sale. Firm i 's installed base changes according to the transition function

$$Pr(b'_i|b_i, q_i) = \Delta(b_i + q_i - b'_i|b_i), \quad b'_i = q_i, 1 + q_i, \dots, b_i + q_i, \quad (4)$$

where b'_i corresponds to firm i 's market share at time $t + 1$ and b_i is the market share at time t . If the joint outcome of the depreciation and the sale results in an industry state outside of the state space, the probability that would be assigned to that state is given to the nearest state(s) on the boundary of the state space.

3.4 Bellman Equation and Strategies

The consumer's idiosyncratic preference shocks $\epsilon = (\epsilon_1, \epsilon_2, \epsilon_3)$ and the good that she is loyal to r are stochastic and unknown to the firms when they set prices. Let $V_i(b)$ denote the expected net present value of future cash flows to firm i in state b . The Bellman equation is given by

$$V_i(b) = \max_{d_i \in [0,1], p_i} \mathbb{E}_r \left[\phi_{ri}(b, d_i, d_{-i}(b), p_i, p_{-i}(b)) (p_i - \mathbf{1}(r \neq 0, r \neq i) d_i k) + \beta \sum_{j=0}^2 \phi_{rj}(b, d_i, d_{-i}(b), p_i, p_{-i}(b)) \bar{V}_{ij}(b) \right], \quad (5)$$

where $p_{-i}(b)$ is the equilibrium price charged by firm i 's rival and $d_{-i}(b)$ is the equilibrium proportion of switching costs reimbursed by firm i 's rival, the (constant) marginal cost of production is normalized to zero, $\beta \in [0, 1)$ is the common discount factor, and $\bar{V}_{ij}(b)$ is the expected continuation value to firm i given that firm j wins the current consumer:

$$\bar{V}_{ij}(b) = \sum_{b'} Pr(b'|b, q_j = 1) V_i(b').$$

Computation is carried out using the solver KNITRO in the TOMLAB optimization environment.

In our analysis we consider two reimbursement regimes. For the No Reimburse-

ment (NR) regime, we set $d_i = 0$, $i = 1, 2$, whereas for the Endogenous Reimbursement (ER) regime, we allow firm i to choose any value in $[0, 1]$ for d_i .

3.5 Dynamic Equilibrium

For the equilibrium in the dynamic game, we focus attention on symmetric Markov perfect equilibria (MPE), where symmetry requires that agents with identical states to behave identically, i.e firm 2's MPE strategy given the state $(\hat{b}, \tilde{b})$ are identical to firm 1's MPE strategy given the state $(\tilde{b}, \hat{b})$ for any $\tilde{b}, \hat{b}$. Existence of a symmetric MPE follows from the proof given in Doraszelski and Satterthwaite (2010). In general, there may exist multiple dynamic equilibria, so we use a selection rule provided in the dynamic games literature where we compute the limit of a finite-horizon game as the horizon grows to infinity (Chen et al., 2009).

In the analysis that follows, we will use the terms *effective price* and *network benefit*. The effective price is the expected payment by a consumer who chooses one of the inside goods, taking into account the switching cost and the reimbursement of the switching cost. It is defined as

$$\mathbb{E}_r \left[\frac{\phi_{r1} (p_1 + \mathbf{1}(r=2)(1-d_1)k) + \phi_{r2} (p_2 + \mathbf{1}(r=1)(1-d_2)k)}{\phi_{r1} + \phi_{r2}} \right].$$

For each parameterization (defined below), we compute the effective price in every state and obtain the average across all states using the probabilities in the limiting distribution. That gives us the effective price for that parameterization reported in Figure 6.

The network benefit is the expected network externality enjoyed by the consumer.

It is defined as

$$\theta \mathbb{E}_r[\phi_{r0}0 + \phi_{r1}g(b_1) + \phi_{r2}g(b_2)].$$

For each parameterization, we compute the network benefit in every state and obtain the average across all states using the probabilities in the limiting distribution. That gives us the network benefit for that parameterization reported in Figure 6.

3.6 Parameterization

The key parameters of the model are the strength of network effect θ , the switching cost k , the rate of depreciation δ and the quality of the outside good v_0 . We examine several values for v_0 between $-\infty$ and 0 and set the baseline at -6 , representing a case in which there exists an outside good but it is inferior compared to the inside goods. The lower bound for δ is zero and corresponds to the unrealistic case in which installed bases never depreciate. On the other hand, if δ is sufficiently high then the industry never takes off. We consider many values for δ between 0 and 0.1 and use $\delta = 0.06$ as the baseline. We investigate the following values for the strength of network effect and the switching cost: $\theta \in \{0.5, 1, \dots, 4\}$, and $k \in \{0.5, 1, \dots, 3\}$. While we extensively vary the above key parameters, we hold the remaining parameters constant at $M = 20$ and $\beta = \frac{1}{1.05}$, the latter of which corresponds to a yearly interest rate of 5%.

4 Results

In this model, two types of Markov perfect equilibria emerge: the tipping equilibrium and the splintered equilibrium. The tipping equilibrium is characterized by a bimodal limiting distribution of market shares while the splintered equilibrium is character-

ized by a unimodal limiting distribution of market shares. When the distribution is bimodal, one firm is able to maintain a dominant market position in the long run. A study of the resultant forces shows that whichever firm obtains the initial advantage is able to maintain that advantage in The long run. When the distribution is unimodal, the firms split the market evenly in the long run. A study of the resultant forces shows that from any starting point, the market converges to a symmetric outcome. For the remainder of this section, we will be referring to firm 1 without any loss of generality, as the equilibrium is symmetric.

4.1 The No Reimbursement Regime

Suppose that firms are unable to reimburse switching costs (e.g. price discrimination is made illegal). When the switching costs are low relative to the network effect ($\theta = 3$, $k = 1$), the market settles on a tipping equilibrium, as illustrated in Figure 1. The limiting distribution, which is depicted in Figure 1(6), demonstrates the bimodal nature of the equilibrium. Figure 1(4) shows that even the smallest of advantages leads to convergence on the mode corresponding to the firm with the greater initial installed base. This is the larger firm. When the switching costs are low, it is relatively easy for a firm to lose customers. There are two mechanisms at play that induce customers to switch: the price and the network effect. Figure 1(1) presents firm 1's pricing policy function and Figure 1(5) shows the probability that one of firm 1's customers switches to firm 2. It is this panel of Figure 1 that depicts the two mechanisms at work.

Note that by way of Figure 1(5), when the firms' market shares are even they engage in vigorous price competition, representing the "bargain" phase of the bargain-then-ripoff strategy where the firms invest in growing their installed base. At this

point, the probability of firm 1's customer switching to firm 2 is relatively low at about 0.2. If firm 1 gains the slightest advantage, then both firms' prices increase somewhat symmetrically initiating the "ripoff" phase as firms harvest surpluses from their installed base; however, the strong network effect decreases the probability of switching to nearly zero. As firm 1's advantage grows, the relatively strong network effect allows firm 1 to increase its price at a greater rate than firm 2. The increase in the price differential generates an upward trend in the probability of switching, though the probability still remains below the initial value of 0.2. If, on the other hand, firm 2 is able to obtain the initial advantage. The prices both increase as discussed above. The difference is now the probability of a firm 1 customer switching jumps up by approximately 300%, to 0.6. As firm 2's advantage grows, the price differential increases and the probability of switching decreases down to approximately 0.4 in the long run, still 100% above the initial value. Naturally, if either firm begins with an advantage, the same pattern holds, only without the "bargain" phase.

When switching costs are high relative to the network effect ($\theta = 3$, $k = 3$), a tipping equilibrium is no longer sustainable and the economy transitions to a splintered equilibrium, as illustrated in Figure 2. A bargain-then-ripoff strategy is no longer employed. Figure 2(1) shows that while prices are still non-monotonic, they are always above marginal cost except when a firm has little-to-no installed base, at which point the firm drops its price to marginal cost. While prices are, in general, increasing as a firm's installed base, there is a spike when the market is fully covered and split evenly. Given the relatively high switching cost, the firms are able to harvest surpluses from their consumers as the network effect is no longer strong enough to induce switching. This outcome is problematic for consumers because the market settles on this symmetric outcome with high prices in the long run, as depicted in Figures 2(4) and 2(6). Another key distinction between the low and high switching cost

cases is the probability of switching, which is shown in Figure 2(5). Not surprisingly, the probability of switching is lower in general because the switching cost is higher. When firm 1 has very little market share, it prices at-or-near marginal cost while firm 2 charges a price nearly 40 times higher, harvesting its installed base. Thus the probability of a firm 1 customer switching is near zero while the probability of a firm 2 customer switching is at 0.15, implying the transition towards a more symmetric outcome depicted in Figure 2(4). As the market shares become more symmetric, firm 1 increases its price rapidly. Firm 2's price exhibits a slight decrease, but is then followed up with an increase at a lower rate than firm 1's price increase. The network effect is becoming less significant as the market shares converge. Thus in the long run, the market settles on relatively high prices.

The above can be summarized as follows.

1. Under the NR regime, as the switching cost increases, market concentration, as measured by the HHI, decreases.
2. Under the NR regime, as the switching cost increases, the effective price increases.
3. Under the NR regime, as the switching cost increases, the network benefit decreases.

Combining points 2 and 3 yields a fourth result.

4. Under the NR regime, as the switching cost increases, consumer welfare decreases.¹⁴

The relationship between the switching cost, network effect and market concentration is depicted in Figure 5(3), the relationship between the switching cost, network

¹⁴Consumer welfare is normalized by setting to zero the surplus of a consumer who uses the outside option.

effect and effective price is depicted in Figure 6(1) and the relationship between the switching cost, network effect and consumer welfare in the NR regime is depicted in Figure 6(7).

4.2 The Endogenous Reimbursement Regime

Now suppose that firms simultaneously choose prices and the proportion of switching costs to reimburse. To coincide with the NR regime, we divide the analysis into two cases. Firstly we look at the case in which the switching cost is small relative to the network effect and then we look at the case in which the switching costs are high relative to the network effect.

First take ($\theta = 3$, $k = 1$). Much like the NR regime at these parameter values, the economy converges to a tipping equilibrium. Moreover, the price policy function, resultant forces and limiting distribution remain unchanged from the NR regime and are depicted in Figures 3(1), 3(4) and 3(6), respectively. The key distinction between the NR and ER regimes is thus how the dominant firm is able to maintain its dominant position and how the firms' reimbursement strategies affects consumers. In the tipping Markov perfect equilibrium, both firms will reimburse at least some portion of the switching cost. This result is depicted in Figure 3(2).

If firm 1 and firm 2 start with equal market shares, only a small proportion of the switching costs are reimbursed. If firm 1 is able to obtain an advantage, then the firm sharply increases the proportion of switching costs it reimburses. Given the strength of the network effect, firm 2 is unable to compete with firm 1 on this margin and thus has no incentive to sharply increase its reimbursements. Instead, firm 2 does its best to simply maintain by charging a price only slightly above marginal cost. At the mode of the limiting distribution, the probability of a firm 1 customer switching sits

below 0.25 while the probability of a firm 2 customer switching is more than double at over 0.5.

In the second case, where switching costs are high relative to the network effect ($\theta = 3, k = 3$), the results run in stark contrast to the NR regime. Unlike the NR regime, a dominant firm can maintain its dominance even with an increase in the switching cost, and the economy remains in a tipping equilibrium. That is, a large firm can counteract the effects of the increased switching cost. The first thing to note is that the shape of the price policy function still maintains the same general shape as the other tipping equilibria; however, the peak is greater and the trough is lower. That is to say, the bargain is greater but the ripoff is worse. This is illustrated in Figure 4(1). The general shape of the reimbursement policy function, given in Figure 4(2), resembles that of Figure 3(2), which corresponds to the ER regime with $k = 1$.

The resultant forces and limiting distribution, given in Figures 4(4) and 4(6), also resemble the ER regime with $k = 1$. The key distinction is the increase in the switching cost globally decreases the probability of a firm 1 (or firm 2) customer switching, which can be seen by comparing Figures 3(5) and 4(5). The firm maintains its dominance by taking advantage of the increased switching cost increasing its price, but by a lower proportion than the increased switching cost. It then uses these surpluses to subsidize new customers via the reimbursement channel.

When incorporating various switching costs between $k = 1$ and $k = 3$, it turns out that between 50% and 70% of all switching costs are reimbursed. The above can be summarized into three main results.

5. Under the ER regime, as the switching cost increases, market concentration, as measured by the HHI, increases.
6. Under the ER regime, as the switching cost increases, the effective price in-

creases.

7. Under the ER regime, as the switching cost increases, the effect network effect increases.

As a consequence, a fourth result emerges.

8. Under the ER regime, as the switching cost increases, consumer welfare decreases.

4.3 Comparing the NR and ER Regimes

This comparison seeks to address a fundamental question: what are the affects of price discrimination in markets characterized by switching costs? When couched in terms of policy, this discussion illuminates on whether governments should allow firms to charge new customers and returning customers different prices. We focus this section on three elements: the effective price, the network benefit and most importantly, consumer welfare.

Recall that result 2 showed that as switching costs increase, the effective price increases under the NR regime. The same also holds true under the ER regime, as illustrated in result 6. Although both are increasing, it turns out that consumers may actually face a lower effective price in the ER regime, even when k is large.¹⁵ Furthermore, as the network benefit is strictly decreasing in the switching cost under the NR regime while the network benefit is increasing in the ER regime, consumers receive a strictly greater average network benefit under the ER regime, as illustrated by Figures 6(4), 6(5) and 6(6), respectively. These results are important, as they show that even though the market is more concentrated (higher HHI), the effective price is lower and the network benefits are greater then the less concentrated market without

¹⁵See Figures 6(1), 6(2) and 6(3).

reimbursement. Therefore an anti-trust authority relying on the HHI must be careful in industries with switching costs. If the firms are practicing price discrimination via a reimbursement channel, then consumer welfare is actually greater in these markets than they would be if the pricing strategies of the participating firms were to be restricted by the authority. This is illustrated diagrammatically in Figures 6(7), 6(8) and 6(9).

[To be added: results from a broader set of parameterizations.]

5 Concluding Remarks

This paper developed a dynamic duopoly model of price competition with switching costs, where firms have the ability to reimburse their competitor's consumer's switching costs. We used the model to study the conditions under which switching costs are reimbursed, what proportion is reimbursed, and how competition and welfare are affected by these decisions. This setup yields several interesting results.

When firms cannot reimburse switching costs, i.e. price discrimination is not possible, an increase in the switching costs causes a transition from a tipping equilibrium where one firm dominates the market to a splintered equilibrium in which the firms split the market equally. Introducing the ability to reimburse switching costs benefits the larger firm and allows it to achieve dominant provision. The economy remains in the tipping equilibrium regardless of the magnitude of the switching cost. Even though the market is more concentrated, consumer welfare is higher than the case where switching costs cannot be reimbursed and the firms split the market evenly. This result has important anti-trust and consumer welfare policy implications, illustrating that relying on the HHI in industries with switching costs may be problematic.

There is still much to learn by way of switching cost reimbursement. For example,

this paper treated the switching cost as exogenous. In some industries this is not the case. For example, early termination fees in television and wireless contracts represent an endogenous switching costs. Thus firms often face three decisions: the price of the good, the endogenous component of their own good's switching cost, and the proportion of their competitors' switching costs to reimburse. It would then be interesting to explore how making switching costs endogenous would affect the reimbursement decision or the HHI.

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(1) Firm 1's price policy function

(2) Firm 1's reimbursement policy function

(3) Firm 1's value function

(4) Resultant forces

(5) Probability of an $r = 1$ consumer switching to firm 2

(6) Limiting distribution

Figure 1. No reimbursement (NR): Tipping equilibrium at low switching cost.
 $v_0 = -6$, $\delta = 0.06$, $\theta = 3$, $k = 1$.

(1) Firm 1's price policy function

(2) Firm 1's reimbursement policy function

(3) Firm 1's value function

(4) Resultant forces

(5) Probability of an $r = 1$ consumer switching to firm 2

(6) Limiting distribution

Figure 2. No reimbursement (NR): Splintered equilibrium at high switching cost. $v_0 = -6$, $\delta = 0.06$, $\theta = 3$, $k = 3$.

(1) Firm 1's price policy function

(2) Firm 1's reimbursement policy function

(3) Firm 1's value function

(4) Resultant forces

(5) Probability of an $r = 1$ consumer switching to firm 2

(6) Limiting distribution

Figure 3. Endogenous reimbursement (ER): Tipping equilibrium at low switching cost. $v_0 = -6$, $\delta = 0.06$, $\theta = 3$, $k = 1$.

(1) Firm 1's price policy function

(2) Firm 1's reimbursement policy function

(3) Firm 1's value function

(4) Resultant forces

(5) Probability of an $r = 1$ consumer switching to firm 2

(6) Limiting distribution

Figure 4. Endogenous reimbursement (ER): Tipping equilibrium at high switching cost. $v_0 = -6$, $\delta = 0.06$, $\theta = 3$, $k = 3$.

(1) Switching cost reimbursement, NR

(2) Switching cost reimbursement, ER

(3) Market concentration, NR

(4) Market concentration, ER

Figure 5. Switching cost reimbursement and market concentration. $v_0 = -6$, $\delta = 0.06$.
NR: No reimbursement. ER: Endogenous reimbursement.

Figure 6. Effective price, network benefit, and consumer welfare. $v_0 = -6$, $\delta = 0.06$. NR: No reimbursement. ER: Endogenous reimbursement.