Reimbursing Consumers’ Switching Costs in Network Industries

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October 2018

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, thereby 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 reimburses a greater share of the switching cost than the smaller firm does, as an additional instrument to propel itself to market dominance. Consequently, an increase in the switching cost increases market concentration. Compared to the case without switching cost reimbursement, allowing firms the option to reimburse results in greater consumer welfare despite having a higher market concentration, as consumers are helped by larger network benefits and often lower effective prices.

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

Some of the largest and most important network industries in the economy are characterized by switching costs. For instance, switching health insurance plans often requires consumers to switch primary care providers as well (Strombom et al., 2002). Credit card markets are also characterized by switching costs, where switching lenders requires 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 network 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 price discrimination by offering different prices to first-time buyers, repeat buyers and competitors’ customers. This form of price discrimination is sometimes referred to as consumer recognition, behavior-based price discrimination (BBPD), or history-based price discrimination. In many cases, such price discrimination emerges as switching costs reimbursements. For example, Verizon Wireless reimburses up to $650 in consumers’ switching costs if they switch to Verizon Wireless. Similar strategies are used by other carriers, such as Sprint and T-Mobile. Similarly, many banks offer cash or non-cash benefits to new customers who switch to them, helping defray these customers’ switching costs.

In this paper, we take the infinite-horizon duopoly model with network effects and an outside option developed in Chen (2016), where firms compete in prices, and extend it to allow for the reimbursement of switching costs. Specifically, we have firms choose the proportion of consumers’ switching costs to reimburse. The firms are forward looking and dynamically optimize. Price discrimination occurs through the reimbursement channel. We use the model to understand when a firm will choose to reimburse consumers’ switching costs.

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1 The markets are sometimes referred to as customer markets (Cabral, 2016). For a survey of the literature, see Fudenberg and Villas-Boas (2006).
costs, and how such reimbursements affect the competition and the market outcome.

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 (as of January 2018) for a one-year subscription AutoCAD by Autodesk ranges from $1,176-$1,470. 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. A firm can help defray consumers’ switch costs by offering new consumers a price discount and/or resources such as free training.

We use numerical methods to calculate a Markov perfect equilibrium of the model. We then use this equilibrium to investigate how the firms’ pricing and reimbursement decisions influence the long-run industry dynamics and how the market outcome depends on the magnitude of the switching cost and strength of the network effect. Under the interaction of network effects, switching costs, and proportional reimbursement, two qualitatively distinct types of equilibria emerge. The first type is a tipping equilibrium, in which one firm dominates the market. This equilibrium satisfies the property of market dominance discussed in the network goods literature. The second type is a splintered equilibrium, in which the firms split the market with nearly symmetric shares. This equilibrium satisfies the property of reversion to the mean (the complement of market dominance) discussed in Cabral (2011).

We build our analysis by studying two regimes. In the first regime, the firms do not have the ability to reimburse the consumers’ switching cost. We call this regime the no

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5For more details, see Farrell and Klemperer (2007), Cabral (2011), and the citations therein.
reimbursement (NR) regime and it serves as a benchmark that allows us to consider how competition is affected by the reimbursement decision. This regime replicates the results of Chen (2016) using appropriate parameter values for comparison. This regime is similar to the models of Suleymanova and Wey (2011) and Doganoglu and Grzybowski (2013), which study static and two-period environments, respectively. A steady-state approach to a similar environment is given in Keller et al. (2010). In the second regime, each firm simultaneously chooses its price and the proportion of consumers’ switching cost it wishes to reimburse. We call this regime the endogenous reimbursement (ER) regime. This paper is among the first to study such price discrimination in the presence of both switching costs and network externalities.

Under the NR regime, we find that switching costs tend to reduce market concentration, sometimes dramatically so. This result is consistent with the existing literature for both non-network goods with switching costs (Beggs and Klemperer 1992; Chen and Rosenthal 1996; Taylor 2003) and network goods with switching costs (Suleymanova and Wey 2011; Doganoglu and Grzybowski 2013; Chen 2016). We show that an increase in the switching cost can transform the market from a tipping equilibrium where market concentration is high to a splintered equilibrium where market concentration is much lower. Thus switching costs can break the increasing market dominance result found in the network goods literature, mitigating the risk of market monopolization, as a firm with an initial advantage may see that advantage eroded away through competition.

Under the ER regime, we find that the larger firm offers a larger reimbursement to switching consumers than the smaller firm does, as an additional instrument to propel itself to market dominance. Correspondingly, an increase in the switching cost does not transform the market from a tipping equilibrium to a splintered equilibrium. To the con-

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6In an extension, Suleymanova and Wey (2011) present a two-period extension to their static model.

7Moreover, a qualitatively similar result has been shown in the network goods literature without switching costs when firms are relatively impatient (low discount factor), as illustrated in Cabral (2011).

8Note that switching costs can be interpreted as a form of horizontal product differentiation. However, switching costs do not typically involve the costs associated with product differentiation, such as R&D expenditures, and thus serve as a mechanism to limit market power and monopolization. Moreover, switching costs can eliminate initial advantages that horizontal differentiation may not be able to eliminate.
trary, it increases market concentration by affecting the probabilities of both attracting new consumers and retaining repeat consumers. Thus reimbursement qualitatively negates the market-share effects of switching costs, though consumers and firms are still affected through the differences in pricing strategies. Without network effects, previous research has shown that history-based price discrimination makes highly competitive markets more competitive and less competitive markets even less so (Cabral, 2016). Moreover, prices are shown to decrease in the switching cost for small switching costs (Dube et al., 2009; Cabral, 2016). We show that the interaction of both network effects and switching costs, when coupled with reimbursement, can lead to relatively less competitive markets regardless of the initial competitive state of the market, with the effective prices consumers face increasing in the switching cost.

Compared to the NR regime, consumers under the ER regime receive greater welfare even though the market is more concentrated. The reason is that under the ER regime, consumers benefit from larger network benefits and often lower effective prices. The result shows that in markets for network goods characterized by switching costs, a higher market concentration does not correspond to a less desirable outcome for the consumers. In fact, consumers prefer the ER regime over the NR regime even though the latter results in a market in which the competing firms are more symmetric. In industries with switching costs and no network effects, such price discrimination can have negative effects on consumer welfare (Gehrig et al., 2011). More generally, however, total welfare effects in markets with switching costs are ambiguous (Bouckaert et al., 2012; Cabral, 2016).

In network industries without switching costs, the effects of higher market concentration on consumer welfare is generally unclear. Mitchell and Skrzypacz (2006) show that there are too many active firms in equilibrium relative to the social planner’s ideal. This result can be interpreted as market shares being too symmetric, which implies that increased market concentration is welfare improving, but may not always be the equilibrium outcome. In the

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9 Extremely asymmetric market shares become only slightly more symmetric, but there is still a significant degree of asymmetry in the long run of the splintered equilibrium. We cannot make more general statements on comparative statics regarding prices and switching costs, as Cabral (2016) that they are highly dependent on both functional form and relative magnitudes.
context of compatibility, which acts as a concentration of the network effect, [Shy (2011)] illustrates that although social welfare is often higher under compatibility, consumer welfare typically decreases, as the benefits from an increased network size are more-than offset by a corresponding increase in price (Shy, 2011, pp. 127-128). Thus the interaction of switching costs and network benefits appears to have unique effects relative to the separate cases of network benefits and switching costs. Therefore antitrust analysis that relies on the level of market concentration must be extra careful in industries with consumer switching costs and the reimbursement of such costs.

**Related Literature.** This paper adds to the interrelated literatures on network goods, switching costs, and price discrimination. The literature on switching costs can be traced back to [von Weizsäcker (1984)]. Shortly thereafter, these markets were examined in [Klemperer (1987a), Klemperer (1987b), and Klemperer (1987c)]. 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)] and the literature review in [Cabral (2016)].

We make several key departures from the existing literature.

An important finding in the literature on switching costs is that switching costs incentivize firms to harvest their locked-in consumers rather than price aggressively for market dominance, and therefore switching costs tend to make markets less concentrated.

Adding to this literature, the current paper shows that if firms have the option to reimburse consumers’ switching costs, then an increase in switching costs actually increases market concentration.

[Chen (1997)] and [Shaffer and Zhang (2000)] are among the first papers to study discriminatory pricing in the context of switching costs. Using a two-period homogeneous-good duopoly 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. The paper finds that

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10See, for example, [Beggs and Klemperer (1992), Chen and Rosenthal (1996), Taylor (2003), Farrell and Klemperer (2007), and Chen (2016)].
discriminatory price is not a function of the firm’s market share, which follows from the model having a finite time horizon. In the present paper, we consider an infinite-horizon model in which firms set both price and switching cost reimbursement. As a result, we find that both the pricing and reimbursement decisions depend explicitly on the firm’s market share.

Shaffer and Zhang (2000) study the properties of price discrimination in a static model with switching costs. They show that when demand is symmetric, a firm charges a lower price to its rival’s consumers (paying to switch). However, when demand is asymmetric, a firm charges a lower price to its own consumers (paying to stay). In the present paper, we incorporate dynamic competition into the analysis and show that in the dynamic equilibrium, each firm reimburses a portion (potentially all) of consumers’ switching costs, in essence charging a lower price to its rival’s consumers and a higher price to its own consumers.

Several recent papers, including Dube et al. (2009), Arie and Grieco (2014), Rhodes (2014), Fabra and García (2015), and Cabral (2016), study switching costs in dynamic infinite-horizon models of price competition. Except for Dube et al. (2009), Fabra and García (2015), and Cabral (2016), these papers have focused on the case in which firms cannot discriminate between locked-in and not locked-in consumers. Dube et al. (2009) and Cabral (2016), along with Fudenberg and Tirole (2000), Gehrig et al. (2011), and Bouckaert et al. (2012) also relate to the literature on history-based price discrimination.

In addition to allowing for this type of price discrimination, we also incorporate network benefits. Complementing these existing studies, we focus on the comparison between the case with price discrimination in the form of switching cost reimbursement and the case without such price discrimination. We show that the market outcome crucially depends on whether firms have the option to reimburse consumers’ switching costs.

Cabral (2016) studies the effects of switching costs in a dynamic competitive environment in which sellers can discriminate between locked-in and not locked-in consumers. He

Farrell and Shapiro (1988) and Farrell and Shapiro (1989) are some of the first dynamic infinite-horizon models of price competition with switching costs. These works abstract from switching cost reimbursement and price discrimination. The authors find that in the absence of price discrimination, switching costs have pro-entry effects.
shows that if markets are very competitive to begin with, then switching costs make them even more competitive (closer to a symmetric duopoly); whereas if markets are not very competitive to begin with, then switching costs make them even less competitive. In this paper, we consider the effects of switching costs on market competitiveness from a different angle, and show that if firms have the option to reimburse consumers’ switching costs, then switching costs make the market less competitive, otherwise they make the market more competitive.

The literature on network effects has existed and developed alongside the switching cost literature. More recently, studies have emphasized the dynamic nature of network effects, such as Mitchell and Skrzypacz (2006) and Cabral (2011). Recent surveys include Birke (2009) (empirical) and Shy (2011) (theoretical).12 Mitchell and Skrzypacz (2006) was among the first papers to study long-run industry dynamics in the presence of network effects, finding that there is too little standardization in the long run (too many active firms) under product homogeneity relative to a social planner’s ideal. Computational models of markets with network effects include Doganoglu (2003), Markovich (2008), Markovich and Moenius (2009), and Chen et al. (2009). These papers emphasize pricing strategies, standardization (Markovich and Markovich and Moenius), and compatibility, respectively.

In the past few years, a few papers have emerged that combine network effects and switching costs. Keller et al. (2010) take a steady-state approach to study the mobile phone market assuming both myopic consumers and firms. We keep the myopic consumer assumption but consider forward-looking firms. Suleymanova and Wey (2011) consider a static model with a two-period extension, where uniform pricing is assumed. Doganoglu and Grzybowski (2013) consider a two-period model and, similar to Suleymanova and Wey (2011), require uniform pricing. To our knowledge, this paper is the first to have both network effects and switching costs and to allow for non-uniform history-based price discrimination (in the form of reimbursements).

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

2 Typologies of Switching Costs and Their Reimbursement

A switching cost is the disutility a consumer receives when transitioning from one good to another. There are several ways to classify switching costs along different dimensions. Nilssen (1992) dichotomizes 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 consumer’s first use of a product.

Shapiro and Varian (1999) provide a classification of the various types of switching costs, including those arising from contractual commitments, durable purchases, brand-specific training, information and databases, specialized suppliers, search costs, and loyalty programs, respectively.

Burnham et al. (2003) develop a switching cost typology that identifies three types of switching costs. 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, and the indirect channel, where the firm reduces the switching cost through non-monetary means. Wireless carriers reimbursing their competitors’ early termination fees are an example of the direct channel. Software companies offering free file conversion service or free training for new users are examples of the indirect channel.

The objective of the present paper is to provide some general insights about the effects of switching costs and their reimbursement in network industries. Towards that end, we do
not tailor the model to any specific type of switching costs or reimbursement. Instead, we
develop a more generic model to capture the key features of many markets characterized
by network effects, switching costs, and the reimbursement of switching costs by firms.

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 single-product
firms indexed by $i = 1, 2$. The firms compete in prices, selling to a sequence of buyers with
unit demands. Denote by $p_i$ the price for good $i$ and by $p = (p_1, p_2)$ the vector of prices.
The 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. At the beginning of a period, a firm is endowed with an installed base
which represents users of its product. $b_i \in \{0, 1, \ldots, M\}$ denotes the installed base of firm
$i$, where $M$ represents the size of the consumer population and is the upper bound on the
sum of the firms’ installed bases. Therefore, $b_1 + b_2 \leq M$. $b_0 = M - b_1 - b_2$ is the outside
good’s installed base. The industry state is given by $b = (b_1, b_2)$, where the state space is

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

In each period, given $b$, the firms simultaneously decide what proportion of consumers’
switching costs to reimburse and what 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 $d = (d_1, d_2)$. 

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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. The utility a consumer loyal to good $r$ gets from purchasing good $i$ is

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

where $v_i$ is the intrinsic product quality, which is fixed over time and common across firms ($v_i = v, i = 1, 2$), and $\epsilon_i$ is the consumer’s idiosyncratic preference shock. As the intrinsic quality parameter affects demand only through the expression $v - v_0$, we set $v = 0$ without loss of generality and consider different values for $v_0$.

We assume that it is costly for consumers to switch between inside goods, and use $k > 0$ to denote the switching cost. In real-world industries, some switching costs are exogenous and some are endogenous. For example, transaction costs, learning costs, and search costs are typically exogenous and not much affected by firms’ actions. In contrast, contractual commitments and loyalty programs are endogenous, as they are the result of firms’ actions. In this paper, we focus on exogenous switching costs and abstract from the endogenous ones. Generalizing the model to also include endogenous switching costs is a useful avenue for future research (in that case each firm will have three choice variables: price, switching cost, and reimbursement of the competitor’s customers’ switching cost).

In our model, a 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 $d_i > 0$.\(^\text{13}\)

The increasing $C^2$ function $\theta g(\cdot)$ captures the network effect, where $\theta \geq 0$ controls the 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, $g(b_i) = \frac{b_i}{M}$.\(^\text{14}\)

\(^{13}\)A 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, which we vary.

\(^{14}\)We have also allowed $g(\cdot)$ to be convex, concave, and S-shaped. The main results are robust to these
When a consumer reevaluates her purchase, she chooses the good that offers the highest current utility. We are then assuming that consumers make myopic decisions. Such a parsimonious specification of consumers’ decision-making allows for rich modeling of firms’ decisions and industry dynamics. Allowing consumers to be forward-looking with rational expectations in the presence of both network effects and switching costs is an important but challenging extension of the current work.

We assume that $\epsilon_i$ 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

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

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, exactly one consumer’s good dies, returning the consumer to the market. Therefore, with probability $\frac{b_1}{M}$, firm $i$’s installed base depreciates by 1 at the start of the period. The two firms then compete for this consumer. For example, suppose that the consumer currently on the market consumed firm 1’s good in the previous period. Then in the current period, firm 1 offers this consumer a price of $p_1$ to retain her. Firm 2 offers this consumer a price of $p_2$ while also simultaneously offering to reimburse $d_2 \times 100\%$ of the switching cost. Therefore, the realized price of good 2 is $p_2 + (1 - d_2)k$. With probability $\phi_{11}(b,d,p)$, firm 1 retains this consumer. With probability $\phi_{12}(b,d,p)$, firm 2 steals this consumer. With the complementary probability $1 - \phi_{11}(b,d,p) - \phi_{12}(b,d,p)$, the consumer chooses the outside good. Let $Pr(b'|b)$ denote the probability of transitioning to state $b'$ given the current state $b$. Note that the only feasible transitions given $b = (b_1, b_2)$ are $b' = (b_1, b_2), b' = (b_1 + 1, b_2 - 1), b' = (b_1 - 1, b_2 + 1), b' = (b_1 + 1, b_2),$ and $b' = (b_1, b_2 + 1)$.
The first state corresponds to retention. The next two states correspond to a firm capturing a competitor’s consumer. The latter two represent market growth and only occur if the consumer on the market previously consumed the outside good. The transition probability \( Pr(b' | b) = 0 \) for all infeasible transitions (those not listed above).

### 3.4 Bellman Equation

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

\[
V_i(b) = \max_{p_i,d_i} \mathbb{E}_r \left[ \phi_{ri} (b, d_i, d_{-i}(b), p_i, p_{-i}(b)) \right. \\
+ \left. \beta \sum_{j=0}^{2} \phi_{rj} (b, d_i, d_{-i}(b), p_i, p_{-i}(b)) \hat{V}_{ij}(b) \right],
\]

where \( p_{-i}(b) \) is the equilibrium price charged by firm \( i \)’s rival, \( d_{-i}(b) \) is the equilibrium proportion of the switching cost 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 \( \hat{V}_{ij}(b) \) is the expected continuation value to firm \( i \) given that firm \( j \) wins the current consumer:

\[
\hat{V}_{ij}(b) = \sum_{b'} Pr(b' | b) V_i(b'),
\]

where \( b' \) is the next-period industry state.

### 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., for any \( \hat{b}, \check{b} \), firm 2’s MPE strategy given the state \( (\hat{b}, \check{b}) \) are identical to firm 1’s MPE strategy given the state \( (\check{b}, \hat{b}) \). 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 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). Computation of the MPE via value function iteration is carried out using MATLAB and the solver KNITRO in the TOMLAB optimization environment.

3.6 Parameterization

For the quality of the outside good, we set $v_0 = -5$, which represents the scenario in which the inside goods’ intrinsic quality is much higher than the outside good’s and consequently the inside goods’ combined market share is not far from 100%. In addition, we consider $v_0 = 0$ in an extension, which represents the scenario in which the outside good’s quality is similar to the inside goods’, so that the outside good captures a substantial market share. We set the number of consumers $M$ to 20, which, given our modeling of the random depreciation of installed bases described above, corresponds to a depreciation rate of $1/20 = 0.05$. We investigate the following values for the strength of network effect and the switching cost: $\theta \in \{0, 0.5, ..., 5\}$ and $k \in \{0, 0.25, ..., 3\}$, for a total of $11 \times 13 = 143 \theta-k$ combinations. Finally, we hold the firms’ discount factor constant at $\beta = \frac{1}{1.05}$, 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. In the tipping equilibrium, the firm that obtains an initial advantage is able to build on that advantage and dominate the market in the long run, resulting in a high level of market concentration. In contrast, in the splintered equilibrium, starting from any industry state the market converges to a symmetric outcome, and in the long run the two firms share the market about evenly. For the remainder of this section, we will be referring to firm 1 without loss of generality, as the two firms’ policy functions are symmetric to each other.
4.1 The No Reimbursement (NR) Regime

First suppose firms are unable to reimburse consumers’ switching costs (e.g., if price discrimination is made illegal). In an industry featuring strong network effects, there is a tipping equilibrium when the switching costs are low, as illustrated in Figure 1 ($\theta = 2, k = 1$), and there is a splintered equilibrium when the switching costs are high, as illustrated in Figure 2 ($\theta = 2, k = 2$). What follows is qualitatively similar to Chen (2016) using different parameter values that allow for comparison to the ER regime. Our results are distinct from Suleymanova and Wey (2011) as initial market shares do not affect market structure. Initial market shares only affect which firm maintains a dominant position in the case in which there is a dominant firm.

**Low Switching Costs.** First consider the tipping equilibrium at low switching costs. Panels 5 and 6 of Figure 1 show the evolution of the industry structure over time. They plot the 15-period transient distribution of installed bases, which gives the probability distribution of the industry state after 15 periods, starting from state $(0, 0)$ in the first period, and the limiting distribution, which gives the probability distribution of the industry state as the number of periods approaches infinity, respectively. Both the transient distribution and the limiting distribution are bimodal, indicating that over time, the industry moves towards asymmetric states, and the market tends to be dominated by a single firm. This result is consistent with the network goods literature without switching costs, e.g., Katz and Shapiro (1985) and Cabral (2011).

Panel 4 plots the resultant forces, which report the expected movement of the state from one period to the next. The panel shows that even the smallest of advantages leads to convergence towards the modal state in which the initial leader dominates the market. The switching cost literature, without network effects, argues that highly competitive markets become more competitive and relatively uncompetitive markets become even less so (Cabral 2016). Thus we are able to show that incorporating network effects has a significant effect on this outcome. Even if the market is almost perfectly symmetric, the process moves
towards an asymmetric tipping equilibrium. This outcome, however, does resemble the market dominance outcome in Cabral (2011), indicating that low switching costs do not have much of an impact on the properties of network industries when network effects are strong.

There are two factors about the firms’ products that could induce consumers to switch: the price and the network effect. Panel 1 presents firm 1’s price policy function and Panel 3 shows the probability that a consumer loyal to firm 1 switches to firm 2. Examination of these two panels allow us to better understand the two factors at work.

Panel 1 shows that when the firms’ market shares are even they engage in fierce price competition, hoping to gain an initial advantage which would propel them to become a dominant firm. This results in a deep trench along and around the diagonal of the state space, representing very low prices. When one firm gains an advantage, market tipping takes place and the smaller firm gives up the fight (to the left of the diagonal, firm 1 is the smaller firm, and to the right of the diagonal, firm 1 is the larger firm). Correspondingly, the smaller firm increases its price substantially. In response the larger firm also increases its price, but keeps it lower than the smaller firm’s until it has achieved a significant installed base advantage over its smaller rival. Therefore, during most of the market evolution, both the network effect factor and the price factor work in favor of the larger firm, as it has a larger network and charges a lower price. As a result, in Panel 3 we see that the larger firm’s customers rarely switch to the smaller firm, whereas the smaller firm’s customers frequently switch to the larger firm. This pattern in the consumers’ switching behavior allows the larger firm to achieve and maintain market dominance. This pricing strategy resembles the harvesting and investing effects described in Chen (1997), Shaffer and Zhang (2000), Farrell and Klemperer (2007), and the citations therein.

High Switching Costs. We now turn to the splintered equilibrium at high switching costs. Panel 1 of Figure 2 shows that a firm’s price is always strictly above marginal cost (which has been normalized to 0) except when it has little-to-no installed base, at which point it drops its price to marginal cost. While prices are, in general, increasing with the
firm’s own installed base, there is a spike when the market is fully covered and evenly split. The high switching costs incentivize the firms to harvest their locked-in consumers (Farrell and Klemperer 2007) rather than price aggressively for market dominance (Cabral 2011, p. 84). As a result, the market settles on a symmetric outcome (Panel 6) with high prices in the long run. This result is consistent with much of the literature on switching costs without network effects, e.g. Beggs and Klemperer (1992), the literature on network effects without switching costs (Mitchell and Skrzypacz 2006), and the intersection of the two (Suleymanova and Wey 2011). This result, however, runs counter to Fabra and García (2015), who using a continuous time duopoly with switching costs but no network effects, find that there is always convergence to a splintered equilibrium.

When the smaller firm has little-to-no installed base, it prices at or near marginal cost while the larger firm charges a much higher price to harvest its locked-in consumers. Correspondingly, the probability of the smaller firm’s customer switching is close to zero while the probability of the larger firm’s customer switching is much higher at around 0.2 (Panel 3), implying the transition towards a more symmetric outcome. This outcome implies a form of reversion to the mean discussed in Cabral (2011), where the larger firm is both more likely to have its consumers on the market (due to the constant hazard rate) and its consumers more likely to switch. Consequently, Panel 4 shows that there is global convergence of the industry state towards the symmetric modal state, resulting in a low level of market concentration. When combined with network effects, the bargain-then-ripoff strategy (Farrell and Klemperer 2007) often observed with switching costs no longer occurs. Instead, prices are globally above marginal cost and firms leverage their network size with higher prices, as is often observed in the networks literature without switching costs, e.g. Katz and Shapiro (1985, p. 425) and Cabral (2011, p. 84).

4.2 The Endogenous Reimbursement (ER) Regime

Now suppose firms simultaneously choose price and the proportion of switching costs to reimburse. To coincide with the NR regime, we again divide the analysis into two cases:
when the switching costs are low, and when the switching costs are high.

**Low Switching Costs.** First consider \( \theta = 2 \) and \( k = 1 \). Much like the NR regime at these parameter values, a tipping equilibrium occurs. Moreover, the price policy function, resultant forces and limiting distribution remain similar from the NR regime and are depicted in Figure 3, Panels 1, 4, and 6, respectively.

In the equilibrium, both firms reimburse at least some portion of the switching cost. For a sufficiently asymmetric market share, the full switching cost is reimbursed by the larger firm. This result is depicted in Panel 2. When the two firms have equal market shares, only a modest proportion of the switching cost is reimbursed. If firm 1 is able to obtain an advantage, then the firm sharply increases the proportion of switching cost it reimburses to 100% or slightly lower in an effort to attract its competitor’s customers and propel itself to a dominant position. 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 increase its reimbursement. Instead, firm 2 chooses to reimburse a small proportion of the switching cost, around 20%. At the mode of the limiting distribution (Panel 6), i.e., when \((b_1, b_2) = (14, 6)\) or \((6, 14)\), the probability of the larger firm’s customer switching sits at merely 0.24 while the probability of the smaller firm’s customer switching is a lot higher at 0.60 (Panel 3). Correspondingly, the market converges to a highly asymmetric outcome (Panel 4). Thus for small switching costs relative to network benefits, the network benefits dominate and as a result, we see the market asymmetries often associated with network goods.

**High Switching Costs.** When the switching cost is high \((\theta = 2, k = 2)\), the results run in stark contrast to the NR regime and [Chen (2016)]. Unlike the NR regime, the larger firm can achieve and maintain its dominance even at a high switching cost, and the economy remains in a tipping equilibrium. That is, by using the switching cost reimbursement as a strategic instrument, the large firm is able to counteract the effects of the increased switching cost.

The first thing to note is that the price policy function (Figure 4(1)) maintains the
same general shape as in the other tipping equilibria (Figures 1(1) and 3(1)). However, the
trench is lower and the peak is higher. For instance, under the ER regime, the lowest price
along the trench in firm 1’s price policy function is -3.72 when \( k = 1 \) (Figure 3(1)), and
is much lower at -5.58 when \( k = 2 \) (Figure 4(1)). Also, the peak in firm 1’s price policy
function (which occurs at state \((b_1, b_2) = (20, 0)\)) is 2.64 when \( k = 1 \) (Figure 3(1)), and is
noticeably higher at 3.12 when \( k = 2 \) (Figure 4(1)). This indicates that given endogenous
reimbursement of switching costs, instead of foiling the preemption race and market tipping,
an increase in the switching cost actually makes them more pronounced: the firms price
more aggressively when they are neck and neck, and the eventual market winner enjoys a
higher price markup.

Here’s the intuition for the above patterns. Compared to the smaller firm, the larger
firm has a larger pool of locked-in consumers, so it has a stronger incentive to charge
high prices in order to “harvest” its locked-in consumers. An increase in the switching
costs strengthens the degree of consumer lock-in and therefore strengthens the larger firm’s
harvesting incentive. If there isn’t the option to reimburse rival’s customers’ switching
costs, the larger firm’s ability to charge high prices to its locked-in consumers is restricted,
as a high price charged to all consumers would make it less likely that the larger firm
can attract new customers and expand its installed base. The option to reimburse rival’s
customers’ switching costs solves this dilemma for the larger firm. Its strategy is then to
charge a higher price to its locked-in consumers to take advantage of the higher switching
costs, while compensating new customers by using switching costs reimbursement. Such a
strategy, combined with the fact that the larger firm has a larger network and therefore a
better product, means that the larger firm can both harvest its locked-in consumers and
attract new consumers at the same time. Hence our finding above that under the ER
regime, the dominant firm enjoys a higher price markup when switching costs are higher.
Correspondingly, the reward to being the dominant firm is bigger, and this bigger reward in
turn makes the initial preemption race even fiercer, which explains the other finding above,
that the firms price more aggressively when they are neck and neck.
The remaining panels in Figures 4 \((k = 2)\) resemble their counterparts in Figure 3 \((k = 1)\). The key distinction is that the increase in the switching cost globally decreases the probability of consumer switching, which can be seen by comparing Figures 3(3) and 4(3). Moreover, examination of the probabilities in the limiting distribution shows that when the switching cost increases from 1 to 2, the industry spends more time in more asymmetric states, which is consistent with what we find above, namely, the higher switching cost actually makes market tipping and winner-take-most more pronounced. In fact, the long-run market concentration (measured as the larger firm’s share of installed base, i.e., \(b_L/M\) where \(b_L\) denotes the larger firm’s installed base, and weighted by the limiting distribution) is 0.72 when \(k = 1\), and increases to 0.76 when \(k = 2\), indicating an increase in market concentration.

4.3 Comparing the NR and ER Regimes

This subsection seeks to address a fundamental question: what are the effects of price discrimination in markets characterized by switching costs and network effects\(^{15}\)? When couched in policy terms, this discussion illuminates on whether governments should allow firms to charge new customers and returning customers different prices in such markets. We focus this discussion on four elements of the market outcome: the market concentration, the network benefit, the effective price, and most importantly, the consumer welfare.

Figure 5 plots for the first two elements, the market concentration and the network benefit. Each panel in the figure plots a variable of interest for different combinations of \(\theta\) (the network effect) and \(k\) (the switching cost).

**Market Concentration.** Panel 1 of Figure 5 shows that in markets with strong network effect \((\theta \geq 2.5)\), under the NR regime an increase in the switching cost can lead to a significant drop in the level of market concentration. For example, with \(\theta = 2\), an increase from \(k = 1\) (corresponding to the parameterization depicted in Figure 1) to \(k = 2\)

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\(^{15}\)Recall that this question has been studied considering only switching costs by Dube et al. (2009), Fabra and García (2015), and Cabral (2016).
(Figure 2) causes the market concentration to drop from 0.70 to 0.57. As discussed above, in this case the increase in the switching cost changes the type of equilibrium that occurs in the market, from a tipping equilibrium at low switching costs to a splintered equilibrium at high switching costs.

In contrast, Panel 3 shows that under the ER regime, an increase in the switching cost increases the level of market concentration, sometimes dramatically so. For example, with $\theta = 2$, an increase from $k = 1$ (corresponding to the parameterization depicted in Figure 3) to $k = 2$ (Figure 4) causes the HHI to increase from 0.72 to 0.76 (both are tipping equilibria). With $\theta = 1$, an increase from $k = 1$ to $k = 2$ causes the HHI to increase from 0.61 (a splintered equilibrium) to 0.70 (a tipping equilibrium).

This pattern is due to the fact that under the ER regime, a higher switching cost gives the larger firm an additional edge, in that the larger firm, by reimbursing a bigger proportion of consumers’ switching cost, is able to expand its advantage in attracting switching customers.

Panel 5 plots the difference in the HHI between the NR and ER regimes. Consistent with the above discussion, we see that for every $(\theta, k)$ combination, the ER regime results in a higher HHI than the NR regime. The difference is particularly large when both $\theta$ and $k$ are large—in this area of the parameter space, the NR regime results in a splintered equilibrium, whereas the ER regime results in a tipping equilibrium.

**Network Benefit.** We next consider the network benefit. Here the term *network benefit* refers to the expected network externality enjoyed by the consumer, and is defined as $\theta E_r [\phi_r 0 + \phi_r 1g(b_1) + \phi_r 2g(b_2)]$. 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 as weights.

In a tipping equilibrium, the dominant firm offers a large network and its product is used by the majority of consumers. In contrast, in a splintered equilibrium, neither firm offers a particularly large network as the two firms split the market about evenly. Therefore, under the NR regime, we expect the network benefit to be larger in a tipping equilibrium than in a splintered equilibrium. Panel 2 of Figure 5 confirms this intuition and shows a
noticeable drop in network benefit when the market changes from a tipping equilibrium to a splintered equilibrium as the switching cost increases.

We see a different picture for the ER regime. Under the ER regime, an increase in the switching cost increases market concentration and therefore results in a larger network enjoyed by the majority of the consumers. Consequently, under the ER regime, the network benefit is expected to increase in the switching cost. This intuition is confirmed in Panel 4, which shows that as the switching cost increases, the network benefit increases.

Turning to the difference between the NR and ER regimes, Panel 6 shows that compared to the NR regime, the ER regime results in a larger network benefit for the consumers. This corresponds to what we find in Panel 5, namely, the ER regime results in a higher market concentration than the NR regime.

This finding points to the possibility that the price discrimination under the ER regime may be beneficial to the consumer. However, to actually find out whether the consumer is better off under the ER regime, we need to also examine how much the consumer pays for the product that she chooses, taking into account the prices charged by the firms, the switching costs, and the reimbursement of switching costs by the firms. This information is shown in Figure 6, which plots the effective price and the consumer welfare for different combinations of $\theta$ and $k$.

**Effective Price.** Here the term *effective price* refers to the expected payment by the consumer when she chooses one of the inside goods, taking into account the switching costs and the reimbursement of switching costs. It is defined as

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

For each parameterization, we compute the effective price in every state and obtain the average across all states using the probabilities in the limiting distribution as weights.

The left column of Figure 6 plots the effective price for the NR regime, the ER regime, and the difference between the two regimes. We see that under both the NR regime (Panel
1) and the ER regime (Panel 3), the effective price increases as the switching cost increases. This runs in contrast to Arie and Grieco (2012), who consider a similar computational approach but find the price to be decreasing in the switching cost (Arie and Grieco 2012, pp. 394-395). There are two differences between our approach and Arie and Grieco (2012): our model includes network effects and there is no switching cost with respect to the outside good. Similar to our result, Fabra and Garcia (2015) find that the average price is increasing in the switching cost when market shares are sufficiently asymmetric, which is the case in our limiting distribution under the tipping equilibrium, where the effective prices are calculated.

Turning to the comparison between the NR regime and the ER regime, Panel 5 shows that the change in the effective price from NR to ER is ambiguous and can be either positive or negative. Among the 143 \((\theta, k)\) combinations plotted in Panel 5, the price change is negative for about half of the combinations (72 out of 143) and ranges from -0.81 to 1.31. The bottom line here is that although the ER regime results in higher network benefit for the consumers, such benefit does not come at the cost of much heightened prices.

**Consumer Welfare.** Lastly, we consider the consumer welfare. Panels 2 and 4 of Figure 6 show that under both the NR regime and the ER regime, an increase in the switching cost lowers consumer welfare, resembling similar environments without network effects, such as Arie and Grieco (2012). Although there are increased benefits from the network effects and larger networks, these benefits are captured by the firms through the higher prices generated by increased lock-in, so consumer welfare still falls. However, as the switching cost increases, consumer welfare decreases more rapidly under the NR regime than under the ER regime. Correspondingly, Panel 6, which plots the change in consumer welfare from NR to ER, shows that the ER regime results in higher consumer welfare, particularly when the switching cost is high. Examination of Figures 5(6), 6(5), and 6(6) shows that at high switching costs, when the network effect is strong, the increased consumer welfare under ER comes primarily from a higher network benefit, and when the network effect is weak, the increased consumer welfare under ER comes primarily from a lower effective price.

\[16\text{Consumer welfare is normalized by setting to zero the surplus of a consumer who uses the outside option.}\]
These results have important policy implications, as they show that with endogenous reimbursement of switching costs, even though the market is more concentrated (higher HHI), the network benefit is greater and the effective price is often lower than a less concentrated market without switching cost reimbursement. Therefore an antitrust authority relying on the HHI must be extra 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 it would be if such price discrimination were to be restricted by the authority.

4.4 Alternative Specifications

In this subsection we consider two alternative specifications of the model, the first regarding the shape of the network effect function, and the second regarding the quality of the outside good.

4.4.1 Shape of the Network Effect Function

In the main analysis of this paper, we have worked with a linear network effect function, namely, \( g(b_i) = \frac{b_i}{M} \). Below we follow Chen et al. (2009) and consider three different shapes of the network effect function in addition to the linear one:

1. Linear: \( g(b_i) = \frac{b_i}{M} \).
2. Convex: \( g(b_i) = \sin \left( \frac{b_i}{M} \times \frac{\pi}{2} + \frac{3\pi}{2} \right) + 1 \).
3. Concave: \( g(b_i) = \sin \left( \frac{b_i}{M} \times \frac{\pi}{2} \right) \).
4. S-shaped: \( g(b_i) = \frac{\sin \left( \frac{b_i}{M} \times \pi + \frac{3\pi}{2} \right) + 1}{2} \).

Figure 7 plots these four network effect functions. Figure 8 reports the results based on each of these four functions. The two columns of Figure 8a report for the linear and convex functions, respectively, and the two columns of Figure 8b report for the concave and S-shaped functions, respectively.
The results depicted in Figure 8 show that our main findings are robust to these alternative functional forms of network effects. In particular, across all these different network effect functions, we find that under the NR regime, an increase in the switching cost can change the market from a tipping equilibrium to a splintered equilibrium, thereby significantly lowering the level of market concentration, whereas under the ER regime, an increase in the switching cost increases the level of market concentration. Compared to the NR regime, the ER regime results in higher market concentration, especially when both network effect and switching cost are high.

The results in Figure 8 pertain to market concentration. The results regarding network benefit, effective price, and consumer welfare, which are not reported, convey the same message, namely, the results are similar across the four different network effect functions.

Despite the similarity, there are nuanced differences in the results. From Figure 7, we can see that for intermediate values of a firm’s installed base, between $b_i = 5$ and $b_i = 15$, the $g$ function is the steepest with the S-shaped function and the flattest with the linear function, while the convex and the concave functions have similar, intermediate slopes. Consequently, our intuition is that everything else equal, the S-shaped function gives the larger firm the biggest network effect advantage, thereby resulting in the most asymmetric market structure in equilibrium, while the opposite holds true for the linear function.

The results support the above intuition. Consider an industry with a large firm and a small firm. Suppose, for instance, the larger firm has an installed base $b_L = 15$, and the smaller firm has an installed base $b_S = 5$. What’s the network effect advantage that the larger firm has relative to the smaller firm? The answer depends on the functional form of the network effect function. Let $\Delta g(b_L, b_S) \equiv g(b_L) - g(b_S)$ denote the difference between the values of the $g$ function for the two firms. Calculation shows that $\Delta g(15, 5)$ is the highest with the S-shaped function at 0.71 and the lowest with the linear function at 0.50. In between those two, $\Delta g(15, 5)$ equals 0.54 for both the convex function and the concave function.

In terms of the equilibrium market concentration, we find that the S-shaped function
results in the most concentrated market, followed by the convex function and the concave function, while the linear function results in the least concentrated market, although the differences are small. Specifically, under the NR regime, across all the $\theta$-$k$ combinations considered in Figure 8, the average market concentration is 0.662 (lowest), 0.676, 0.671, and 0.705 (highest) for the linear, convex, concave, and S-shaped functions, respectively. Similarly, under the ER regime, across all the $\theta$-$k$ combinations considered in Figure 8, the average market concentration is 0.753 (lowest), 0.758, 0.760, and 0.772 (highest) for the linear, convex, concave, and S-shaped functions, respectively.

Figure 9 presents a more specific example. Consider the case with network effect $\theta = 3$. Figure 9 plots the equilibrium market concentration as switching cost $k$ is varied between 0 and 3, under the NR regime and the ER regime, respectively. We see that under both regimes, the market concentration is the highest with the S-shaped network effect function and the lowest with the linear function, while the convex function and the concave function are in-between.

In summary, the results from these different functional forms of the network effect function show that our main findings are robust to these alternative specifications. Furthermore, among the four network effect functions, the S-shaped function results in the highest market concentration, whereas the linear function results in the lowest market concentration, although the differences are small.

4.4.2 Quality of the Outside Good

In this paper our focus is industries like the mobile phone industry and the banking industry, in which the inside goods’ intrinsic quality is much higher than the outside good’s and consequently the inside goods’ combined market share is not far from 100%. Correspondingly, our numerical analysis has focused on the case with $v = 0$ and $v_0 = -5$, so that $v_0$, the outside good’s quality, is much lower than $v$, the inside goods’ quality.

Below we consider an alternative scenario in which the outside good’s quality is similar to the inside goods’, so that the outside good captures a substantial market share. Specifically,
we increase $v_0$ to 0 while keeping $v$ unchanged at 0. The results are reported in Figure 10. For comparison purposes, we report the $v_0 = -5$ results in the left column of Figure 10, and report the $v_0 = 0$ results in the right column.

First, consider the NR regime (Panels 1 and 2). Consistent with the finding in Chen (2016), the results here show that with an inferior outside good ($v_0 = -5$ in Panel 1), high switching costs can substantially lower the market concentration and change the market from a tipping equilibrium to a splintered equilibrium, but with a strong outside good ($v_0 = 0$ in Panel 2), an increase in switching costs no longer lowers the market concentration.

The intuition for the case with $v_0 = 0$ is that a strong outside good acts as a non-strategic player and reduces the firms’ ability to charge high prices to their loyal consumers, because these consumers can choose the outside good if the prices charged by the firms are too high. As a result, the presence of a strong outside good prevents the splintered equilibrium—which involves the firms evenly splitting the market and charging high prices—from happening.

Second, consider the difference between the NR regime and the ER regime (Panels 5 and 6). With an inferior outside good ($v_0 = -5$ in Panel 5), allowing the firms the option to reimburse consumers’ switching costs makes a big difference in the market structure, particularly for the parameterizations with both high network effects and high switching costs, increasing the market concentration by as much as 0.26. In comparison, with a strong outside good ($v_0 = 0$ in Panel 6), allowing the firms the option to reimburse consumers’ switching costs also increases the market concentration, but the magnitude of the change is much smaller: the biggest increase in the market concentration is only 0.03.

Here’s the intuition for the case with $v_0 = 0$. When the outside good’s quality is similar to the inside goods’, the firms compete not only against each other, but also against the outside good, which now has a substantial market share. In fact, under $v_0 = 0$, across all the $\theta$-$k$ combinations considered in Figure 10, the average market share of the outside good is 41.9%, compared to only 1.2% under $v_0 = -5$. Therefore, when $v_0 = 0$, in equilibrium there are a lot of consumers who are loyal to the outside good. Since a consumer loyal to the outside good does not face switching costs, the reimbursement of switching costs now
plays a less significant role in shaping the industry structure, as it is now applicable to a smaller portion of the consumer population. Consequently, with $v_0 = 0$, changing from the NR regime to the ER regime no longer results in drastic changes in the market structure.

The results in Figure 10 pertain to market concentration. The results regarding network benefit, effective price, and consumer welfare, which are not reported, convey the same message, namely, when there exists a strong outside good, giving firms the option to reimburse consumers’ switching costs does not significantly alter the market outcome.

5 Concluding Remarks

This paper develops a dynamic duopoly model of price competition with switching costs and network effects, where firms have the ability to reimburse consumers’ switching costs. We use the model to investigate firms’ pricing and reimbursement strategies and how competition and welfare are affected by these strategies. This setup yields several interesting results.

When firms cannot reimburse consumers’ switching costs, i.e., when price discrimination is not possible, an increase in the switching cost causes a transition from a tipping equilibrium where one firm dominates the market to a splintered equilibrium in which the firms split the market about evenly. Introducing the ability to reimburse switching costs benefits the larger firm and facilitates market tipping and winner-take-most. A consequence is that the economy remains in a tipping equilibrium even at high switching costs. Even though the market is more concentrated, consumer welfare is higher than the case in which switching costs cannot be reimbursed. This finding has important antitrust and consumer welfare policy implications, illustrating that in industries with switching costs, policy analysis relying on the HHI may be problematic.

There is still much to learn about switching costs and their reimbursement. For example, this paper has focused on exogenous switching costs and abstracted from the endogenous ones. In some industries endogenous switching costs are an important factor. For instance,
early termination fees in television and wireless contracts represent 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 cost to reimburse. It would then be interesting to explore how making switching costs endogenous would affect firms' pricing and reimbursement decisions, the market structure, and ultimately, the welfare in the economy.

**References**


Figure 1. No reimbursement (NR): Tipping equilibrium at low switching cost. $v_0 = -5, \delta = 0.05, \theta = 2, k = 1.$
(1) Firm 1’s price policy function

(2) Firm 1’s reimbursement policy function

(3) Probability of a firm 1’s customer switching to firm 2

(4) Resultant forces

(5) Transient distribution after 15 periods

(6) Limiting distribution

Figure 2. No reimbursement (NR): Splintered equilibrium at high switching cost. $v_0 = -5$, $\delta = 0.05$, $\theta = 2$, $k = 2$. 
Figure 3. Endogenous reimbursement (ER): Tipping equilibrium at low switching cost. $v_0 = -5, \delta = 0.05, \theta = 2, k = 1.$
(1) Firm 1’s price policy function

(2) Firm 1’s reimbursement policy function

(3) Probability of a firm 1’s customer switching to firm 2

(4) Resultant forces

(5) Transient distribution after 15 periods

(6) Limiting distribution

Figure 4. Endogenous reimbursement (ER): Tipping equilibrium at high switching cost. $v_0 = -5, \delta = 0.05, \theta = 2, k = 2.$
Figure 5. Market concentration and network benefit. $v_0 = -5$, $\delta = 0.05$.
NR: No reimbursement. ER: Endogenous reimbursement.
Figure 6. Effective price and consumer welfare. $v_0 = -5$, $\delta = 0.05$.
NR: No reimbursement. ER: Endogenous reimbursement.
Figure 7. Linear, convex, concave, and S-shaped network effect functions.
(1) Market concentration, NR, linear $g(\cdot)$

(2) Market concentration, NR, convex $g(\cdot)$

(3) Market concentration, ER, linear $g(\cdot)$

(4) Market concentration, ER, convex $g(\cdot)$

(5) Market concentration, ER-NR, linear $g(\cdot)$

(6) Market concentration, ER-NR, convex $g(\cdot)$

Figure 8a. Alternative specification: shape of network effect function. $v_0 = -5$, $\delta = 0.05$.
NR: No reimbursement. ER: Endogenous reimbursement.
Left column: linear $g$ function. Right column: convex $g$ function.
Figure 8b. Alternative specification: shape of network effect function. \( v_0 = -5, \delta = 0.05 \).
NR: No reimbursement. ER: Endogenous reimbursement.
Left column: concave \( g(\cdot) \) function. Right column: S-shaped \( g(\cdot) \) function.
Figure 9. Market concentration, $v_0 = -5$, $\delta = 0.05$, $\theta = 3$. 
(1) Market concentration, NR, $v_0 = -5$

(2) Market concentration, NR, $v_0 = 0$

(3) Market concentration, ER, $v_0 = -5$

(4) Market concentration, ER, $v_0 = 0$

(5) Market concentration, ER-NR, $v_0 = -5$

(6) Market concentration, ER-NR, $v_0 = 0$

Figure 10. Alternative specification: $v_0, \delta = 0.05$.
NR: No reimbursement. ER: Endogenous reimbursement.
Left column: $v_0 = -5$. Right column: $v_0 = 0$. 