Switching Costs and Network Compatibility

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Preliminary & Incomplete - Comments Welcome!

Abstract

This paper investigates how consumer switching costs affect firms’ compatibility choices and welfare in network industries. Firms face a choice between two modes of competition: make their networks incompatible and fight for market dominance, or make their networks compatible and peacefully share the market. By incentivizing firms to harvest their locked-in consumers rather than price aggressively for market dominance, switching costs tip the balance in favor of compatible networks and peaceful sharing. A public policy that reduces switching costs also tends to make networks incompatible, and results in small efficiency gains at best. Combining the policy with a mandatory compatibility policy, however, would lead to unambiguous and sizable efficiency gains.

Keywords: switching costs, network compatibility, industry dynamics, welfare

1 Introduction

A product or service has network effect if its value to a consumer increases in the number of its users. Two examples are mobile phone services (network effect comes from discounts for on-net calls) and banking services (network effect comes from branch and ATM networks).

Two important features of network industries are consumers’ switching costs and firms’ compatibility choices. First, consumers can switch between networks but it is often costly
for them to do so (in terms of money and/or effort). For example, when a consumer switches from one mobile phone service provider to another, she needs to tell her new phone number to all her contacts (if phone numbers are not portable between two different providers), and she may have to pay early termination fees. Similarly, when a consumer switches from one bank to another, she needs to tell her new bank and her new account number to all the relevant parties (direct deposits, automatic payments, etc.). In fact, Shy (2001, Page 1) suggests that switching costs are one of the main characteristics of network industries.

Second, firms sometimes make their networks compatible—here compatibility between two networks refers to the ability of consumers in either network to enjoy network effect from both networks. For example, mobile phone service providers may extend their on-net calling discounts to cover each other’s networks, and banks may allow their customers to access their combined ATM networks without extra fees.

In this paper, I investigate the effects of switching costs on network compatibility using a dynamic duopoly model with an infinite horizon. In each period, firms first choose network compatibility and then prices. I numerically solve for a Markov perfect equilibrium of the model, and study how switching costs affect firms’ compatibility choices and welfare.

I find that switching costs tend to induce compatible networks. Firms face a choice between two modes of competition: make their networks incompatible and fight for market dominance, or make their networks compatible and peacefully share the market. By incentivizing firms to harvest their locked-in consumers rather than price aggressively for market dominance, switching costs tip the balance in favor of peaceful sharing, changing the market from fierce competition and incompatible networks to mild competition and compatible networks.

In welfare analysis, I find that in a network industry in which switching costs are high and networks are often compatible, a public policy that reduces switching costs, by itself, does not lead to a significant increase in total surplus, as the efficiency gains from lowering switching costs are offset by the efficiency losses from firms dropping the compatibility between their networks. In this situation, a public policy that mandates compatibility between networks does not generate significant efficiency gains, either, as networks are often compatible to begin with so the requirement makes only a small difference. The combination of these two policies,
however, can lead to unambiguous and sizable efficiency gains, as such a combination makes it possible to have the best of both worlds—low switching costs and compatible networks.

Analysis of how switching costs affect firms’ behavior and market performance is particularly needed in light of the recent and growing trend of regulations that aim at reducing switching costs in network industries in order to increase competition. For instance, in the past decade or so, mobile number portability was implemented in more than forty countries, which reduces mobile phone users’ switching costs by enabling them to retain their phone numbers when changing from one network to another. In the EU retail banking and payments systems markets, the European Competition Authorities Financial Services Subgroup recommends the implementation of switching facilities (objective and up-to-date comparison sites, switching services, etc.) and account number portability to lower switching costs (ECAFSS (2006)). While there are many studies on the effects of switching costs on market concentration and prices, little is known about how a change in switching costs affects firms’ network compatibility choices (shared on-net calling discounts, shared ATM networks, etc.) Since network compatibility can have significant impact on competition and welfare, research on this issue is much needed.

Empirical observations in some real-world industries provide anecdotal evidence that supports the model predictions in this paper. For example, mobile number portability was implemented in Hong Kong in 1999, which reduced consumers’ switching costs. During the implementation period, the mobile phone service providers there dropped the compatibility among their networks (shared on-net calling discounts) by adopting network-based discriminatory pricing schemes. The largest network steadily gained market share following the implementation of mobile number portability, resulting in a higher level of market concentration (Shi, Chiang, and Rhee (2006, pp. 29-30)).

**Related Literature.** One of the main findings in the literature on switching costs is that they make markets less concentrated (see, for example, Beggs and Klemperer (1992), Chen and Rosenthal (1996), Taylor (2003), and Chen (2015)). Adding to that literature, the current paper examines the effects of switching costs in network industries on both the market structure and firms’ compatibility choices, and shows that switching costs tend to induce
compatible networks, which go hand in hand with a lower level of market concentration.

A number of existing papers investigate whether compatibility will emerge in a standard two-stage model without switching costs: in the first stage, firms make compatibility decisions, and then given such decisions, they engage in price or quantity competition. Examples include Katz and Shapiro (1986), Economides and Flyer (1997), Cremer, Rey, and Tirole (2000), Malueg and Schwartz (2006), and Tran (2006). These papers find that products are compatible when firms have comparable installed bases (or some other traits).

To go beyond the initial emergence of compatibility and understand whether compatibility will be maintained as the industry evolves over time, one needs to investigate the long-run industry dynamics. A growing body of work explores long-run market structure issues in network industries, including Mitchell and Skrzypacz (2006), Llobet and Manove (2006), Driskill (2007), Markovich (2008), and Cabral (2011), although they do not model firms’ compatibility choices.

Chen, Doraszelski, and Harrington (2009) endogenizes product compatibility in a dynamic stochastic setting and investigates the issue of whether compatibility can be maintained in the long run. They find that products are compatible when firms have similar installed bases, and when random forces result in one firm having a bigger installed base, strategic pricing tends to prevent the installed base differential from expanding to the point that incompatibility occurs. Their paper abstracts from consumer switching costs.

The current paper adds to the above literature by incorporating consumer switching costs into a dynamic model in which firms make both compatibility and price decisions. This allows me to study the long-run effects of switching costs on firms’ compatibility choices and welfare and examine the policy implications.

The rest of the paper is organized as follows. The next section presents the model. Section 3 reviews the dynamic equilibria of the model. Section 4 discusses the effects of switching costs on network compatibility and market concentration. Section 5 examines the welfare effects of two public policies related to switching costs and network compatibility. Section 6 concludes.
2 Model

This section describes a dynamic duopoly model of network industries in which firms have the option to make their networks compatible and consumers face switching costs. This model builds on Chen, Doraszelski, and Harrington (2009) and adds switching costs.

2.1 State Space and Firm Decisions

The model is cast in discrete time with an infinite horizon. Two firms sell to a sequence of buyers with unit demands. Each firm sells a single product and sets price. The firms’ products are referred to as the inside goods, and are durable subject to stochastic death. There is also an outside good (“no purchase”), indexed 0. At the beginning of a period, a firm is endowed with an installed base which represents users of its product. $b_i \in \{0, 1, ..., M\}$ 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. $b_0 = M - b_1 - b_2$ is the outside good’s “installed base”, though it does not offer network benefits. The industry state is $b = (b_1, b_2)$, with state space $\Omega = \{(b_1, b_2) | 0 \leq b_i \leq M, i = 1, 2; b_1 + b_2 \leq M\}$.

In each period, given $(b_1, b_2)$, the firms engage in a two-stage game, choosing compatibility in the first stage and prices in the second stage. In the first stage, each firm decides whether or not to “propose compatibility” with the other firm. Let $d_i \in \{0, 1\}$ be the compatibility choice of firm $i$, where $d_i = 1$ means “propose compatibility.” Products of the two firms are “compatible” if and only if $d_1 \cdot d_2 = 1$. After compatibility is determined, the firms simultaneously choose prices in the second stage.

2.2 Demand

Demand in each period comes from a random consumer who chooses one among the three goods. $r \in \{0, 1, 2\}$ denotes 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 now her product dies and she returns to the market. A consumer may also be loyal to a firm’s product because of her relationship 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 $r$ is distributed according to $\Pr(r = j|b) = b_j/M, j = 0,1,2$, so that a larger installed base implies a larger expected demand from loyal consumers. The utility that a consumer who is loyal to good $r$ gets from buying good $i$ is

$$v_i + 1(i \neq 0)\theta g(b_i + d_1d_2b_{-i}) - p_i - 1(r \neq 0, i \neq 0, i \neq r)k + \epsilon_i.$$ 

Here $v_i$ is the intrinsic product quality, which is fixed over time and is common across firms: $v_i = v, i = 1,2$. Since the intrinsic quality parameters affect demand only through the expression $v - v_0$, without loss of generality I set $v = 0$, and consider different values for $v_0$.

$b_i + d_1d_2b_{-i}$ is the effective installed base of firm $i$ given the compatibility choices, where $b_{-i}$ is the installed base of firm $i$’s rival. The increasing function $\theta g(.)$ captures network effects, where $\theta \geq 0$ is the parameter controlling the strength of network effect. There are no network effects associated with the outside good. The results reported below are based on linear network effects, that is, $g(b_i) = b_i/M$. I have also allowed $g$ to be convex, concave, and S-shaped, and the main results are robust.

$p_i$ denotes the price for good $i$. The price of the outside good, $p_0$, is always zero.

The nonnegative constant $k$ denotes switching cost, and is incurred if the consumer switches from one inside good to the other. A consumer who switches from the outside good to an inside good incurs a start-up cost, which is normalized to 0. Increasing the start-up cost above 0 has the effect of lowering the inside goods’ intrinsic quality relative to that of the outside good.

$\epsilon_i$ is the consumer’s idiosyncratic preference shock. $(\epsilon_0, \epsilon_1, \epsilon_2)$ and $r$ are unknown to the firms when they set prices.

The consumer buys the good that offers the highest current utility. I am then assuming that consumers make myopic decisions. Such a parsimonious specification of consumers’ decision-making allows rich modeling of firms’ prices 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.

Assume $\epsilon_i$ is distributed type I extreme value, independent across products, consumers,
and time. The probability that a consumer who is loyal to good \( r \) buys good \( i \) is then
\[
\phi_{ri}(b, d, p) \equiv \frac{\exp(v_i + 1(i \neq 0)\theta g(b_i + d_1d_2b_{-i}) - p_i - 1(r \neq 0, i \neq 0, i \neq r)k)}{\sum_{j=0}^{2}\exp(v_j + 1(j \neq 0)\theta g(b_j + d_1d_2b_{-j}) - p_j - 1(r \neq 0, j \neq 0, j \neq r)k)},
\]
where \( b \) is the vector of installed bases, \( d \) is the vector of compatibility choices, and \( p \) is the vector of prices.

Note that in this model, switching costs are unchanged when firms make their networks compatible, which fits some real-world examples. For instance, if two banks make their ATM networks compatible by allowing consumers from each network to access the ATMs in the other network for free, a consumer who switches from one bank to the other still incurs the switching cost as she still needs to inform relevant parties (direct deposits, automatic payments, one-click purchases, etc.) of her new account number. Similarly, if two mobile service providers extend their on-net calling discounts to cover both networks, a consumer who switches from one network to the other still incurs the switching cost as she still needs to inform her contacts of her new phone number (if phone numbers are not portable between different providers).

### 2.3 Depreciation and Transition

In each period, each unit of a firm’s installed base independently depreciates with 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
\[
\Delta(x_i|b_i) = \binom{b_i}{x_i} \delta^x_i (1 - \delta)^{b_i-x_i}, \quad x_i = 0, ..., b_i,
\]
as \( x_i \) is distributed binomial with parameters \((b_i, \delta)\). Accordingly \( E[x_i|b_i] = b_i \delta \), 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, \( b_0 = M - b_1 - b_2 \), goes up 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
\[
\Pr(b'_i|b_i, q_i) = \Delta(b_i + q_i - b'_i|b_i), \quad b'_i = q_i, ..., b_i + q_i.
\]
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.

2.4 Bellman Equation and Strategies

The consumer’s idiosyncratic preference shocks and the good that she is loyal to 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 $b$ before compatibility decisions are made, and let $U_i(b, d)$ denote the expected net present value of future cash flows to firm $i$ in state $b$ after compatibility decisions are made and revealed to both firms. For the second-stage game, we have

$$ U_i(b, d) = \max_{p_i} \mathbb{E}_r [\phi_{ri}(b, d, p_i, p_{-i}(b, d))p_i + \beta \sum_{j=0}^{2} \phi_{rj}(b, d, p_i, p_{-i}(b, d))V_{ij}(b)], \quad (4) $$

where $p_{-i}(b, d)$ is the price charged by firm $i$’s rival in equilibrium (given the installed bases and the compatibility choices), the (constant) marginal cost of production is normalized to zero, $\beta \in [0, 1)$ is the discount factor, and $V_{ij}(b)$ is the expected continuation value to firm $i$ given that firm $j$ wins the current consumer:

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

Differentiating the right-hand side of equation (4) with respect to $p_i$ and using the properties of logit demand yields the first-order condition

$$ \mathbb{E}_r [-\phi_{ri}(1 - \phi_{ri})(p_i + \beta \overline{V}_{ii}) + \phi_{ri} + \beta \phi_{ri} \sum_{j \neq i} \phi_{rj} \overline{V}_{ij}] = 0. \quad (5) $$

The pricing strategies $p(b, d)$ are the solution to the system of first-order conditions.

Folding back to the first-stage game, we have

$$ V_i(b) = \max_{d_i \in \{0, 1\}} U_i(b, d_i, d_{-i}(b)), \quad (6) $$

where $d_{-i}(b)$ is the compatibility choice of firm $i$’s rival given the installed bases.
2.5 Equilibrium

I focus attention on symmetric Markov perfect equilibria (MPE), where symmetry means agents with identical states are required to behave identically. Following the literature on numerically solving dynamic stochastic games (Pakes and McGuire (1994), Pakes and McGuire (2001)), I restrict attention to pure strategies. A symmetric MPE in pure strategies exists, which follows from the existence proof in Doraszelski and Satterthwaite (2010). There may exist multiple equilibria, and I use a selection rule in the dynamic games literature by computing the limit of a finite-horizon game as the horizon grows to infinity (for details see Chen, Doraszelski, and Harrington (2009)).

2.6 Parameterization

The key parameters of the model are the quality of the outside good $v_0$, the rate of depreciation $\delta$, the strength of network effect $\theta$, and the switching cost $k$. I examine $v_0 \in \{-6, -5, \ldots, -2\}$ and use $v_0 = -4$ as the baseline, which represents a case in which there exists an outside good but it is inferior compared to the inside goods, so that most but not all of the market is covered by the firms (a reasonable approximation of real-world examples such as the mobile phone industry and the banking industry). The lower bound for $\delta$ is zero and corresponds to the unrealistic case in which installed bases never depreciate. On the other hand, if $\delta$ is sufficiently high then the industry never takes off. I consider $\delta \in \{0.04, 0.06, \ldots, 0.12\}$ and use $\delta = 0.06$ as the baseline. I investigate the following values for the strength of network effect and the switching cost: $\theta \in \{0, 0.5, \ldots, 4\}$, and $k \in \{0, 0.5, \ldots, 3\}$. The remaining parameters are held constant at $M = 20$ and $\beta = \frac{1}{1.05}$, the latter of which corresponds to a yearly interest rate of 5%.

While the model is not intended to fit any specific industry, the own-price elasticities for the parameterizations that I consider are reasonable compared to the findings in several empirical studies. Specifically, the own-price elasticities for the baseline parameterizations range from $-1.08$ to $-0.48$. These numbers are in line with the own-price elasticities reported

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1With two firms, symmetry means firm 2’s choices in state $(b_1, b_2) = (\hat{b}, \tilde{b})$ are identical to firm 1’s choices in state $(b_1, b_2) = (\tilde{b}, \hat{b})$. 

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in Gandal, Kende, and Rob (2000) (−0.54 for CD players, computed from the results reported in the paper), Clements and Ohashi (2005) (ranging from −2.15 to −0.18 for video game consoles), and Dick (2008) (ranging from −0.87 to −0.12 for banking services). Additionally, the aggregate market shares of the inside goods for the baseline parameterizations range from 86.9% to 99.3%. These numbers are consistent with, for instance, the cellular mobile penetration rates in OECD countries, which averaged at 96.1% in 2007 (OECD (2009)).

3 Types of Equilibria

In this model three types of equilibria emerge, Rising, Tipping, and Compatibility.

Rising Equilibrium. A Rising equilibrium (depicted in Figure 1) occurs when both network effect and switching cost are weak. A firm’s price monotonically rises in its own installed base and falls in its rival’s installed base (see Panel 1, which plots firm 1’s equilibrium price against the firms’ installed bases). Products are generally incompatible, except possibly when the firms have identical installed bases (see Panel 2, which reports the compatibility region, that is, the states for which both firms prefer compatibility and thus products are compatible.).

Panels 3 and 4 show the evolution of the industry structure over time. They plot the 15-period transient distribution of installed bases (which gives the frequency with which the industry state takes a particular value after 15 periods, starting from state (0, 0) in period 0) and the limiting distribution (which gives the probability distribution of the state as the number of periods approaches infinity), respectively. The unimodal transient distribution and limiting distribution show that the market is generally fragmented, as the industry spends most of the time in fairly symmetric states.

Panel 5 plots the probability that a firm makes a sale, and Panel 6 plots the resultant forces, which report the expected movement of the state from one period to the next (for visibility of the arrows, the lengths of all arrows are normalized to 1, therefore only the direction, not the magnitude, of the expected movement is reported). The larger firm wins the consumer with a higher probability (Panel 5). However, the larger firm’s expected size of depreciation is also larger. In a Rising equilibrium, the difference in expected depreciation
more than offsets the difference in expected sales, and as a result the difference in installed bases shrinks in expectation (Panel 6).

**Tipping Equilibrium.** A *Tipping* equilibrium (depicted in Figure 2) occurs when the network effect is strong and the switching cost is modest. There is a deep trench along and around the diagonal of the price function (Panel 1), indicating intense price competition when firms’ installed bases are of comparable size. Once a firm pulls ahead, the smaller firm gives up the fight by raising its price, thereby propelling the larger firm into a dominant position. Products are almost always incompatible (Panel 2).

The transient distribution (Panel 3) and the limiting distribution (Panel 4) are bimodal. Over time, the industry moves towards asymmetric states, and the market tends to be dominated by a single firm. The larger firm enjoys a significant advantage in expected sales (Panel 5), which results from the smaller firm’s willingness to surrender (by charging high prices), and gives rise to the forces that pull the industry away from the diagonal once an asymmetry arises (Panel 6).

**Compatibility Equilibrium.** A *Compatibility* equilibrium (depicted in Figure 3) occurs when the switching cost is strong. Products are compatible when firms have comparable installed bases (Panel 2). In the compatibility region, prices are high, peaking at the point where each firm has half of the consumers (Panel 1). Off of the peak, the smaller firm drops its price in order to bring the industry back to the peak. In particular, around the border of the compatibility region, the smaller firm lowers its price significantly, in an effort to keep the industry in the compatibility region. Away from the peak, the larger firm also drops its price, but that is a response to the smaller firm’s aggressive pricing rather than an effort to achieve market dominance.

The switching cost segments the market into submarkets, with each submarket consisting of consumers that are locked-in by a firm. Firms focus on charging high prices to “harvest” their locked-in consumers, rather than fighting for market dominance. As a result, the market tends to be fragmented, as shown by the unimodal transient distribution and limiting distribution in Panels 3 and 4.

The resultant forces (Panel 6) show global convergence towards the symmetric modal
state. Outside the compatibility region, the larger firm enjoys a larger expected sale, but inside the compatibility region, the smaller firm has an advantage (Panel 5). Such an advantage for the smaller firm results from its aggressive pricing away from the peak, aimed at keeping the industry in the compatibility region.

4 Switching Costs and Compatibility

For the primary dynamic forces of the model to be at work, the relevant part of the parameter space is when the rate of depreciation $\delta$ is neither too low (so that there is customer turnover) nor too high (otherwise the industry never takes off). In that part of the parameter space, the magnitude of switching cost has significant impact on firms’ compatibility choices and the market structure.

Panel 1 in Figure 4 plots the probability that products are compatible (based on the limiting distribution) for different combinations of $\theta$ (strength of network effect) and $k$ (switching cost). The panel shows that when the switching cost is low, the probability of compatible products is small for weak network effect and essentially zero for strong network effect. However, in both cases, the probability of compatible products increases significantly as the switching cost increases, indicating that the switching cost induces firms to make their products compatible.

One consequence of the changes in firms’ compatibility choices and the corresponding mode of competition is that the level of market concentration is affected. Panel 2 shows the expected long-run Herfindahl-Hirschman Index (HHI; based on installed bases and weighted by probabilities in the limiting distribution). The higher is the HHI, the more concentrated the market is. When the network effect is low to modest ($\theta \in [0, 2]$), the HHI is low throughout, increasing slightly in the switching cost. Examination of the policy function and the limiting distribution in this part of the parameter space indicates that the equilibrium gradually morphs from a Rising equilibrium at low switching cost to a Compatibility equilibrium at modest to high switching cost.

When the network effect is modest to high ($\theta \in [2.5, 4]$), the HHI starts with a relatively high level (above 0.6) at $k = 0$. As the switching cost increases, the HHI initially increases
but later drops significantly. When the switching cost is modest, the market is dominated by a single firm (Tipping equilibrium), but when the switching cost is high, the market becomes fragmented (Compatibility equilibrium).

To be added: (1) analysis of firms’ incentives, and (2) results from a broader set of parameterizations.

5 Public Policies and Welfare

In this section we evaluate two public policies in network industries related to switching costs and compatibility. The first policy is a reduction in switching costs, such as the implementation of mobile number portability in the mobile phone industry and the implementation of account number portability in the banking industry. The second policy is mandating compatibility between different networks, such as shared on-net calling discounts and shared ATM networks.

The results are shown in Figure 5. From left to right, the three columns of panels correspond to $\theta = 1, 2, 3$, respectively. Each panel plots how an equilibrium outcome variable is affected when switching costs are varied between 0 and 3. From top to bottom, the five rows of panels pertain to network compatibility, average price, producer surplus (PS), consumer surplus (CS), and total surplus (TS), respectively. Here, compatibility refers to the probability that products are compatible, PS is the industry profits, CS is normalized by setting to zero the surplus of a consumer who uses the outside option, and TS is the sum of PS and CS. All five measures are weighted averages using the probabilities in the limiting distribution as the weights.

In each panel, three compatibility regimes are considered. The first regime is endogenous compatibility. This is the laissez faire regime and corresponds to the model that we have been analyzing so far. The second regime is mandatory compatibility, in which firms optimize with respect to price only, while we impose the condition that networks are compatible. For comparison purposes, we also consider a third regime, prohibited compatibility, in which firms optimize with respect to price only, given that networks are incompatible.

Consistent with our discussions in the previous section, the first row of panels in Figure
5 show that under the endogenous compatibility regime (the dash-dot line), as switching costs are reduced from 3 to 0, firms become less likely to make their networks compatible, bringing the industry farther away from the mandatory compatibility regime (the solid line) and closer to the prohibited compatibility regime (the dotted line).

Rows 2 to 4 show that reducing switching costs lowers price and PS (except when switching costs are small, specifically when \( k \leq 0.5 \)) and increases CS, under each of the three compatibility regimes. This is consistent with the intuition that as it becomes easier for consumers to switch, firms focus more on competing aggressively for each other’s customers and less on exploiting their locked-in customers. The resulting higher intensity of price competition benefits consumers while lowering firms’ profits.

Furthermore, rows 3 and 4 show that both PS and CS increase successively as we move from prohibited compatibility to endogenous compatibility to mandatory compatibility. Everything else equal, making the networks compatible generates larger benefits from network effects, which enlarges the “economic pie” and allows both firms and consumers to be better off. A comparison between rows 3 and 4 shows that the increase in surplus due to mandating compatibility is mostly captured by firms, while consumers see only small gains except when network effects are strong (\( \theta = 3 \)).

The above discussions foreshadow some of the results on TS (row 5). First, since TS is the sum of PS and CS, it also increases successively as we move from prohibited compatibility to endogenous compatibility to mandatory compatibility.

More interesting is the effect of a reduction in switching costs on TS. If we hold the probability of compatible networks fixed, as is the case under either mandatory compatibility or prohibited compatibility, a reduction in switching costs unambiguously increases TS.

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2 In this paper I focus on industries in which there exists an outside good but it is inferior compared to the inside goods (\( v_0 = -4 \) in the baseline, compared to \( v = 0 \)), so that most, but not all, of the market is covered by the firms, such as mobile phone services and banking services. Therefore, the industry profits, which equal the sum of the firms’ sales times average price-cost margin, are close to the average price, because the sum of the firms’ expected sales is close to 1 (due to the inferiority of the outside good), and the marginal cost is normalized to 0. Consequently, in Figure 5, the panels depicting price (second row) and the ones depicting PS (third row) are alike.

3 For the purpose of comparison, the scale of the \( y \)-axis is the same for all panels in rows 3 to 5.
indicating that the increase in CS is bigger than the decrease in PS.

However, under endogenous compatibility, which allows network compatibility to endogeneously change as we vary switching costs, the effect of a reduction in switching costs on TS becomes ambiguous. That’s because the change in TS is now the result of two concurrent changes: the reduction in switching costs, and the consequent reduction in the probability of compatible networks. While the former tends to increase total surplus, the latter tends to reduce it.

Take Panel (14) \((\theta = 2)\) for example. As switching costs are reduced from 3 to 0, TS increases by 12.4% from 5.59 to 6.28 under mandatory compatibility, and increases by 12.1% from 4.92 to 5.51 under prohibited compatibility. Notice that TS is noticeably higher under mandatory compatibility than under prohibited compatibility.

Next consider endogenous compatibility. Under this regime, reducing switching costs from 3 to 1 lowers the probability of network compatibility significantly (from 0.76 to 0.07; see Panel (2)). Correspondingly, the TS in this case moves farther away from the TS under mandatory compatibility (which is higher) and closer to the TS under prohibited compatibility (which is lower), dropping from 5.42 to 5.28 in the process. When switching costs are further reduced from 1 to 0, the probability of network compatibility stabilizes (around 0.07) instead of dropping further, and correspondingly TS increases from 5.28 to 5.58. Overall, as switching costs are reduced from 3 to 0, TS under endogenous compatibility increases by only 2.8% from 5.42 to 5.58.

It is also worth pointing out that starting with \(k = 3\) and endogenous compatibility, the implementation of mandatory compatibility alone does not improve TS by much, either: TS would increase by only 3.1% from 5.42 to 5.59.

However, if the reduction in switching costs from 3 to 0 and the mandatory compatibility are jointly implemented, then there are sizable efficiency gains: TS increases by 15.9% from 5.42 to 6.28. When network compatibility is made mandatory, the reduction in switching costs no longer results in a lower probability of compatible networks, allowing the efficiency gains from lowering switching costs to be preserved.

The policy implication is then the following. In a network industry in which switching costs are high and networks are often compatible, a public policy that reduces switching
costs, by itself, does not lead to a substantial increase in total surplus, as the efficiency gains from lowering switching costs are offset by the efficiency losses from firms dropping the compatibility between their networks. In this situation, a public policy that mandates compatibility between networks does not generate significant efficiency gains, either, as networks are often compatible to begin with so the requirement makes only a small difference. The combination of these two policies, however, can lead to unambiguous and sizable efficiency gains, as such a combination makes it possible to have the best of both worlds—low switching costs and compatible networks.

Of course, in real-world industries, the implementation of any public policy can be costly, and policymakers need to carefully evaluate the costs and benefits of the policies being considered. Nonetheless, the above analysis illustrates the potential efficiency gains that can be achieved by combining the two policies, and the welfare results here can serve as a benchmark for further analysis.

6 Conclusion

In this paper, I investigate how switching costs affect product compatibility and market dynamics in network industries. Firms face a choice between two modes of competition: make their networks incompatible and fight for market dominance, or make their networks compatible and peacefully share the market. By incentivizing firms to harvest their locked-in consumers rather than price aggressively for market dominance, switching costs tip the balance in favor of compatible networks and peaceful sharing.

Accordingly, public policies that reduce switching costs in network industries, such as mobile number portability and banking account number portability, can change the market outcome from compatible networks to incompatible networks. In the former, price competition is mild and the market is often fragmented, whereas in the latter, firms compete fiercely in a preemption race and in the long run the market is likely dominated by one firm.

In a network industry with high switching costs, a switching costs reduction policy alone, or a mandatory compatibility policy alone, would result in small efficiency gains at best, whereas the combination of these two policies would lead to unambiguous and sizable effi-
ciency gains. The findings in this paper call for further research on the design and evaluation of public policies related to switching costs and network compatibility.

References


Tran, D. V. (2006): “Network Externality, Minimal Compatibility, Coordination and Innovation,” University of Texas.
Figure 1. Rising equilibrium: $v_0 = -4, \delta = 0.06, \theta = 1.5, k = 0.5$
(1) Firm 1’s policy function

(2) Compatibility

(3) Transient distribution after 15 periods

(4) Limiting distribution

(5) Probability that firm 1 makes a sale

(6) Resultant forces

Figure 2. Tipping equilibrium: $v_0 = -4, \delta = 0.06, \theta = 3, k = 0.5$
Figure 3. Compatibility equilibrium: $v_0 = -4, \delta = 0.06, \theta = 3, k = 2.5$
Figure 4. Compatibility and market concentration. $v_0 = -4$, $\delta = 0.06$. 
Figure 5. Switching costs, compatibility, and welfare. $v_0 = -4, \delta = 0.06$.
Dotted lines: prohibited compatibility (PC).