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Competing Across Technology-Differentiated Channels: The Impact of Network Externalities and Switching Costs

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Technology-driven commerce channels, such as the Web, possess several unique features that differentiate them from traditional channels. The interaction between firms operating across these differentiated channels involves interesting competitive dynamics that cannot be captured by isolated models of electronic markets. This paper develops a stylized spatial differentiation model to examine the impact of differences in channel flexibility, network externalities, and switching costs on competition between online, traditional, and hybrid firms. A basic model highlighting the moderating influence of the hybrid firm on both channels is extended to account for differential network externalities and switching costs across the two channels. Our analysis indicates that while network effects as well as switching costs lead to the tipping of markets, such tipping occurs primarily due to the moderating effects of the competing channel. More importantly, with network effects an increased market share does not translate into higher profits. Contradictory to conventional wisdom, our results indicate that in a static market, consumers rather than firms, benefit from increasing network externalities, with competitive effects outweighing the surplus-extraction abilities of firms. Our results also highlight the importance of alternative revenue streams and provide insights for firms grappling with issues of channel choice as well as integration and divestiture.

Key words: e-commerce; online retailing; network externalities; switching costs; game-theoretic models
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1. Introduction

The confluence of several factors over the last few years has transformed emerging technology-driven channels such as the Web into important and sophisticated forums for commerce. These technology-driven channels, rather than incremental improvements over traditional channels, have become a significantly differentiated choice for consumers, providing firms with a whole new opportunity to rethink the way business is conducted. The Web, for instance, possesses unique features that traditional channels for commerce lack—customization; interactivity; multimedia abilities; global access unconstrained by time and space limitations; ability to access, store and transmit information inexpensively; and the ability to conduct transactions in real time. These technological capabilities have direct consequences for businesses as well as consumers. In addition, firms now have to compete not only *within*, but also *across* these differentiated channels, with some of the firms competing in multiple channels and transferring competition across them.

At a fundamental level these features drive three key channel parameters that differentiate the online channel from the traditional channel—*channel flexibility*, *positive consumption externalities*, and *market lock-in*. The differences between traditional and emerging technology-driven channels gain greater significance as firms operating within these channels as well as across them compete by leveraging channel features to differentiate themselves while selling the same product or commodity. Determining the optimal choice of pricing strategy and channel mix is nontrivial when there is competition across channels. Differences across channels in the degree of channel flexibility, network externalities, and market lock-in make solution to this problem even less intuitive. The fact that online channels coexist alongside traditional channels, and that each strongly influences the other, has largely been overlooked in the research literature.[1] This paper attempts to fill this gap by explicitly modeling the strategic interaction between firms operating

[1] An exception is the study by Balasubramanian (1998), who examines how direct marketers change the equilibrium market structure in a traditional retail market that is closed to entry for other retailers. The focus here, though, is on the significance of technology-driven channel differences for competition *within* as well as *across* channels.

across these technology-differentiated channels and showing how these key parameters affect competition *within* as well *across* channels. In particular, we ask the following questions.

• How does indirect competition between firms operating across different channels affect their pricing strategies? What is the resulting effect on consumers?

• How do asymmetries in channel-supported network externalities and switching costs affect competitive outcomes across channel boundaries?

• What are the implications of the channel-differentiating parameters for firms' optimal channel choice and configuration, as well as their integration and divestiture strategies?

A simple stylized game-theoretic spatial differentiation model is developed to study the interaction of firms across channels. Results from the basic model highlight the importance of the hybrid firm (a firm that operates across channels) and its moderating influence on the competitive intensities of the two channels. Extending the basic model to account for differential network externalities and switching costs across the two channels brings into question standard results from earlier research on network effects and switching costs that predict "winner-take-all" outcomes. While network effects and switching costs lead to the *tipping* of markets, we find that such tipping occurs primarily due to the moderating effects of the competing channel. In the case of network externalities, a better market share does not translate into higher profits. Contrary to the conventional wisdom of the winning firm benefiting from network effects, we find that in a static market, consumers rather than firms benefit from increasing network externalities. Our results also highlight the importance of alternative revenues streams for online firms and the significance of technological features for channel choice as well as integration and divestiture decisions.

There is a growing body of research that studies competition between online firms. However, most of this research analyzes electronic markets in isolation, focusing largely on their efficiency-enhancing features. In particular, a lot of attention has been paid to the impact of electronic markets on search costs (Bakos 1997) and their welfare-enhancing properties. However, as Bakos (1997) notes, other salient features of e-markets such as network externalities, economies of scale, and switching costs are crucial for their strategic analysis. A number of empirical studies (see Bakos et al. 2004, Brynjolfsson and Smith 2000) have also sought to examine the "efficiency" of online channels. They find that while prices are lower online compared to traditional channels, there is significant price dispersion among online retailers even for homogenous goods (books, CDs and stock trades), and that online channels are not as "efficient" as predicted by economic models. Differentiation between retailers based on channel features is often cited as a reason for this dispersion in prices. Another stream of empirical research (see Peterson et al. 1997, Jarvenpaa and Todd 1997, Bellman et al. 1999) has studied the Web's unique features and their significance for retailing. In one of the few empirical studies that include online, traditional, and hybrid retailers, Ancarani and Shankar (2002) find that the price levels of traditional retailers are 2% higher than the prices of hybrid retailers, which in turn are 6% higher than those at online retailers. They also find significant differences in price dispersion across the two channels, highlighting the differences in the competitive characteristics of online and traditional channels.

The current paper adds to this literature by explicitly modeling the interactions between firms in multiple channels. It emphasizes the importance of technological factors in the electronic channel that affect key channel parameters like channel flexibility, the creation of network externalities, and switching costs. It is widely recognized that network externalities and switching costs play a central role in the "new economy," and that market dynamics as well as firm strategies are very different in such markets compared to conventional ones (Arthur 1996, Farrell and Klemperer 2004). While the research on network externalities and switching costs is relatively recent, their effects on competition within a single channel (or market) are reasonably well understood. (See Katz and Shapiro 1985, 1986 for a discussion of network externalities, and Klemperer 1986, 1987, 1995; Farrell 1990; and Wernerfelt 1985 for research on consumer switching costs.) However, little is known about multichannel competition where the channels differ in the levels of network externalities and switching costs they create—the central focus of this paper.

The rest of this paper is structured as follows. Section 2 elucidates the key technology-driven channel parameters that motivate the analytical models that follow. Section 3 describes the basic model of competition between firms across channels. Section 4 builds on the basic model in §3 to analyze the impact of differential network externalities and differential switching costs on the equilibrium outcomes in the two channels. Section 5 concludes with a discussion of managerial implications.

2. Technology-Enabled Channel Differentiators

Firms selling commodity products can use a number of channel-related features to add consumer value and differentiate their offerings. For example, take the familiar case of books, where the basic physical product sold by all booksellers (online or offline) is identical. Firms in each channel can combine a bundle of complementary value-added features that influence consumer choice and define their competitive position. For instance, online firms can alter the information mix, the product representation, site design, and user interfaces; and can provide consumers with personalization and customization features, product comparison and evaluation systems, prepurchase help and support, as well as transaction processing and ease of purchase (e.g., one-click ordering), delivery, shipping and handling, online customer service, security and service guarantees. Correspondingly traditional "brick-and-mortar" firms can choose store location, access, ambiance, customer service, support, product assortment, organization, etc. Because some of the channel features impose trade-offs, firms within a channel typically differentiate themselves by choosing to emphasize a subset of the features enabled by the channel technology, thereby highlighting different aspects of the customer's buying experience.

In a market with heterogeneous consumer preferences, the set of features chosen by a firm, while being closer to the requirements (or tastes) of some consumers would be less valuable to other consumers with different requirements. In other words, feature choice by firms imposes *misfit costs* (disutilities) on some consumers who desire a different combination of features than the one provided by a firm. It is these misfit costs borne by the consumer, which enable a firm to segment a market and create a differentiated offering that better serves the requirements of the target segment (while being less valuable to other consumers). For instance, consumers with slower Internet connections might face higher disutility due to long wait times and uncertain fulfillment from information and rich media-intensive websites, while others with fast connections might find them highly valuable. Likewise, some consumers might benefit from personalized recommendations and live support enabled by consumer tracking and personalization technologies, while others might find these features to be intrusive.

While firms within a channel differentiate themselves based on their channel features, the level of misfit costs faced by consumers in a channel is itself a function of the channel technology, and hence can be expected to be different for the two channels. A channel with *lower misfit costs* imposes less disutility on consumers whose ideal combination of channel features is not available, and can thus be considered *more flexible*. Technologies such as user profiling, recommendation systems and dynamic generation of Web pages permit extensive customization of websites, thereby enabling firms to reduce misfit costs. There is little opportunity for doing the same for offline firms with features like location, product assortment and layout. Thus, we can expect the online channel to have lower misfit costs than the offline one.

Network externalities and switching costs have long been considered to be the primary factors that differentiate the "new economy" from the traditional one (Arthur 1996). It is these asymmetries in network externalities and switching costs between the online and traditional channels that are our primary focus.

Technological capabilities such as interactivity and real-time communications enable the creation of virtual communities and networks. In particular, brand-based online communities (see McWilliam 2000), including those in health care and online gaming have witnessed a significant growth in recent years, while firms like Amazon.com have leveraged their customer base to add value through user ratings, reviews and feedback. These user communities generate significant direct as well as indirect *network externalities*. The offline channel offers much less scope for such community building, and consequently, a much lower possibility for the creation of network externalities. Also, consumers who initially purchase from a firm may incur a cost in switching to a different provider for future purchases. Switching costs include transaction costs; learning costs; psychological costs, including brand-loyalty and frequent-flyer programs (Farrell and Klemperer 2001). Community effects, personalized offerings as well as uncertainty in product quality also introduce substantial switching costs for online consumers. In addition, there may be costs of subscribing to a competitor's offerings as well as forgoing the benefits that accrue from learning effects for firms providing personalized services. These *switching costs* make it unattractive for consumers to switch to a rival firm, thereby enabling firms to lock-in consumers. For instance, Chen and Hitt (2002) identify system, firm, and consumer characteristics that contribute to switching costs and find the information-mix provided by online brokerages to be an important driver of switching costs. The relative degree of *channel flexibility*, *network externalities* and *market lock-in* that the two channels facilitate would however, depend on the specifics of the industry, product offerings, and technology, among others.

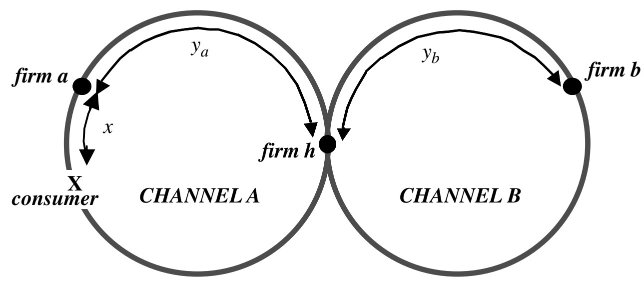
The differences in network externalities and switching costs, for instance, are exacerbated in the case of information goods that were traditionally sold in physical formats (e.g., printed books, audio cassettes, CDs) and are increasingly being sold in digital formats by retailers online. Hybrid retailers such as Tower Records and Wal-Mart sell CDs or cassettes in the traditional channel while selling digital downloads of the same music albums online. The digital formats and technologies used by these online retailers are usually different from, and incompatible with, those of other online retailers such as Apple's iTunes, leading to significant switching costs for consumers. In addition, significant network effects arise when the popularity of a digital format increases the availability of titles in that specific format and spurs complementary technological developments valuable to consumers.

3. The Basic Model

The *basic* model, a stylized spatial differentiation model, is a variant of Salop's (1979) model. It examines the impact of the interactions between pricing and demand across the online and traditional channels that differ in *just* their channel flexibilities. There are three types of firms—a pure online firm that operates in the online Channel A, a traditional "brick-and-mortar" firm that operates in the traditional Channel B, and a hybrid firm that operates in both channels. There are two types of consumers. Consumers of Type A buy only from the online Channel A; there are n_A of them per unit distance. Consumers of Type B buy only from the traditional channel; there are n_B of them per unit distance. This implies that the online and traditional channels cater to different customer segments, with differing needs. The hybrid firm's prices in the two channels are related by a factor k, which captures the markup/discount (due to factors like shipping costs, sales tax, etc.) in the traditional channel over the online channel. The value of k is assumed to be exogenous. A number of hybrid retailers such as Gap, Wal-Mart, Office Depot, Staples, and Schwab, among others, can be seen to adopt uniform-pricing strategies across their traditional and online outlets (see Gulati and Garino 2000 for a discussion of constraints faced by hybrid firms). In a separate technical appendix we derive the optimal value of k (where k is endogenous) when consumers are allowed to switch *across* channels.

Each firm sells a commodity product, but differentiates itself from its rivals by leveraging the characteristics of its own channel and innovating on the features of the buying experience associated with the products, to offer different value propositions. The set of possible differentiated value propositions in each channel is modeled by representing the channel characteristics by a unit circle, and a firm's choice of channel-related value proposition determines its location on the circle. However, this model departs from Salop's (1979) standard model in that the online and the traditional channel are each represented by adjacent unit circles[2] (for instance, see Cooper 1989), with

Figure 1 **Spatial Model of Competition**



the hybrid firm situated at the point of intersection of the two (see Figure 1). Consumers are utility maximizers, and each consumer is in the market for one unit of a product in each period. Each consumer has an ideal configuration of channel-related features (for instance, information mix, multimedia representation, e-mail notifications, and active salesperson involvement) that gives her the highest utility. Consumers are uniformly distributed on each circle according to the position of the peak of their utility functions. Consumers are assumed to have a high reservation price $\check{r}$, in comparison with their total costs. High reservation prices ensure that consumers always purchase a product, so the problem focuses purely on the competitive aspects of the channel (Economides 1989). A consumer incurs a loss of utility when she buys a bundle other than her ideal one, and this depends on the channel *misfit cost* (as noted earlier, *channel misfit cost* is the inverse of *channel flexibility*), which differs across the two channels. The channel misfit costs vary linearly with distance. The total cost incurred by a consumer when she purchases a bundle is the sum of the price she pays for the bundle and the channel misfit cost. Table 1 summarizes the parameters of the basic model.

Firms choose pricing strategies that maximize their profit functions. We assume that the pure online and pure offline firms $[a, b]$ are located diametrically opposite to the hybrid firm in their respective channels, i.e., $y_a = y_b = 0.5$ (see Figure 1). Given their locations, each firm decides on the choice of its price. We analyze the case in which firms, given their locations, simultaneously choose prices.[3] The unique subgame-perfect Nash equilibrium for the price game is characterized in Propositions 1a and 1b. All proofs are available in the appendices.

Proposition 1a. *When the hybrid firm is restricted in its ability to price discriminate across the two channels that*

[2] The circular spatial model (mathematically equivalent to a linear market model of infinite length) has been widely used since Salop (1979) as it avoids the "end-point problems" associated with a line segment of finite length. Also, the assumption of firms' locations corresponds to a subgame-perfect Nash equilibrium, in the case of a circular model.

[3] There exists no equilibrium in pure strategies in a one-stage game involving simultaneous determination of prices and locations with either linear or quadratic cost functions (proofs available upon request). The two-stage game is more realistic as firms' choice of positioning (which is harder to change) usually preceeds their choice of prices.

Table 1 Model Parameters

A, B	Online and traditional channels respectively.
a, b, h	Firms in these channels. Firm a sells exclusively in Channel A, firm b sells exclusively in Channel B, and firm h sells in both channels.
n_i	Size of market served by channel i, $i \in \{A, B\}$
t_i	Cost/unit distance of channel misfit in channel i, $i \in \{A, B\}$
p_i	Price set by firm i, $i \in \{a, b, h\}$
k	Firm h's discount (markup) in Channel B relative to Channel A
x	Distance between the location of the consumer and the firm.
y_a, y_b	Locations of firms a and b relative to firm h.

differ in their channel flexibilities, the hybrid firm always prices between that of the online and the traditional firm.

The equilibrium prices are given in the appendix. It is more informative to look at the following price reaction functions of the three firms.

$$p_a(p_h) = \tfrac{1}{4}(2p_h + t_A) \tag{1.1}$$

$$p_b(p_h) = \tfrac{1}{4}(2kp_h + t_B) \tag{1.2}$$

$$p_h(p_a, p_b) = \frac{n_A t_B(2p_a + t_A) + kn_B t_A(2p_b + t_B)}{4(k^2 n_B t_A + n_A t_B)}. \tag{1.3}$$

Equations (1.1) and (1.2) suggest that the prices of the pure plays in both channels depend only on their own channel characteristics (t_A or t_B), and the price of the hybrid firm. Consequently, we would expect the firms in the channel with higher channel flexibility (lower value of t_i) to compete more fiercely and lower prices, as consumers find their products to be relatively close substitutes. However, the hybrid firm's price (see Equation (1.3)) is a demand-weighted average of parameters (t_A and t_B) of both channels. Thus, the hybrid firm exerts a moderating influence on the competitive intensities of both channels.

Proposition 1b. *The optimal profits at equilibrium for the online firm (firm a), the traditional firm (firm b) and the hybrid firm (firm h) are given by*

$$\pi_a^* = \frac{n_A t_A[2n_A t_B + kn_B(kt_A + t_B)]^2}{16[k^2 n_B t_A + n_A t_B]^2} \tag{1.4}$$

$$\pi_b^* = \frac{n_B t_B[2k^2 n_B t_A + n_A(kt_A + t_B)]^2}{16[k^2 n_B t_A + n_A t_B]^2} \tag{1.5}$$

$$\pi_h^* = \frac{t_A t_B(n_A + kn_B)^2}{4[k^2 n_B t_A + n_A t_B]}. \tag{1.6}$$

The expressions in Propositions 1a and 1b are better understood through Figures A1 and A2, which illustrate the impact of varying channel misfit costs in Channel A on firm prices and profits. As the online channel misfit costs decreases relative to that of the traditional channel (i.e., the online channel becomes more *flexible* relative to the traditional Channel B), online consumers become less sensitive to any differences in the offerings of firms in their channel. In other words, the offerings of competing online firms become closer substitutes, intensifying price competition. However, the hybrid firm, due to its presence in both channels, is sensitive to the competitive conditions in both channels. While the hybrid firm would rather price higher in the traditional channel with higher misfit costs, it has to take into consideration the competition in the online channel in setting its price. Hence, although the pure plays (the pure online and the traditional firms) do not compete for the same set of consumers, the presence of the hybrid firm reacting to competitive conditions in both the channels introduces strategic interdependence between these firms. Also, the channel with higher demand has a greater influence on the prices and profits of all firms. Consequently, as the channel with lower misfit costs grows in size, the hybrid firm competes more intensely with the "pure play" in this channel, adversely affecting the pure play in the alternate channel.

While we have restricted the ability of the hybrid firm to price discriminate freely across both channels (by making k exogenous), we can compare this to the case where the hybrid firm is free to choose k, to highlight how the presence of the "hybrid" firm alters the competitive characteristics of the two channels.

Corollary 1. *When the hybrid firm is free to choose the value of k, it chooses k such that the two channels effectively become independent.*

Corollary 2. *The profits of the pure play in the channel with greater flexibility are substantially lower when the two channels are independent.*

We also find that consumers in the channel that offers greater flexibility (lower misfit costs) benefit more when the two channels are independent, relative to the case where the hybrid firm is restricted in its pricing across channels (i.e., when $k < t_B/t_A$). On the other hand, the welfare of consumers in the less flexible channel improves when the hybrid firm is restricted in its pricing across channels. Lower misfit costs for consumers implies lower prices from both firms in the channel, when the two channels are independent, than when firm h is restricted in its choice of k (see Figure A1, where $k = t_B/t_A$). However, total consumer surplus is greater when the hybrid firm is restricted in its ability to price discriminate across the two channels. Also, as can be seen from Figure A3, consumer surplus in Channel A (Channel B) increases (decreases) with increasing k. The lower the value of k, the more constrained is the hybrid firm in its pricing, leading to a greater transfer of competition across the two channels. In the case of independent channels, consumers in the more competitive channel, A (with lower misfit costs, t_A), benefit from intense price competition. However, with price constraints, the lower the value of k, the higher the implicit value of t_A resulting in a less competitive online channel, and lower consumer surplus. The opposite is true for Channel B.

4. Impact of Network Externalities and Switching Costs

As highlighted earlier, the key parameters that differentiate the online channel from the traditional channel, in addition to channel flexibility, are the degree of *network externalities* that the channel facilitates and the level of *switching costs* for consumers. The *basic* model is extended two ways—one to incorporate the presence of *network externalities* in the online channel and the other to incorporate the presence of *switching costs* for consumers in the online channel. Depending on the product, firm, and industry characteristics, the level of these parameters could be higher or lower in either channel. As the focus is primarily on the differential level of these features across the two channels, we assume (without loss of generality) that there are no externalities or switching costs in the traditional channel.

In the case with *network externalities*, in addition to the utility derived from the bundle, consumers also derive utility from the network of consumers who purchase from the same firm. This is captured by a two-period model, in which a firms' consumer base (demand) in Period I confers utility to the firm's consumers in Period II—the value to a consumer being directly proportional to the number of consumers her firm has in Period I. Thus, a consumer in Channel A, who purchases a bundle from firm a at price p_a^2, located at a distance x from her ideal bundle faces a utility function given by

$$U_i = \check{r} - p_a^2 - t_A(x) + \delta_A \cdot q_a^1$$

where δ_A is the degree of externalities in Channel A and q_a^1 is the Period I demand for firm a. Naturally, a firm with a larger Period I demand is more attractive to a consumer in Period II, ceteris paribus.

Table 2 Additional Model Parameters

A, B	Online and traditional channels respectively.
a, b, h	Firms in these channels. Firm a sells exclusively in Channel A, firm b sells exclusively in Channel B, and firm h sells in both channels.
t_i	Cost/unit distance of channel misfit in channel i, $i \in \{A, B\}$
δ_A	Degree of positive consumption externality in Channel A.
ψ_A	Degree of switching costs in Channel A.
p_i^j	Price set by firm i in period j, $i \in \{a, b, h\}$; $j \in \{1, 2\}$
q_i^j	Market share for firm i in period j, $i \in \{a, b, h\}$; $j \in \{1, 2\}$
π_i^j	Profits for firm i in period j, $i \in \{a, b, h\}$; $j \in \{1, 2\}$

In the case with *switching costs*, consumers face a cost of switching firms in Period II, which makes a consumer reluctant to switch between firms *within* a channel. In addition to the channel-misfit costs, the online consumer faces a switching cost ψ_A of purchasing a product that is different from the one purchased in the first period. Thus, a consumer in Channel A, who has purchased a bundle from firm h in Period I, but purchases from firm a in Period II at price p_a^2, located at a distance x from her ideal bundle faces a utility function given by, $U_i = \check{r} - p_a^2 - t_A x - \psi_A$, where ψ_A is the level of switching costs in Channel A. Table 2 summarizes the additional model parameters.

As in the basic model, consumers seek to maximize utility (minimize cost) and firms seek to maximize profits. The unique subgame-perfect Nash equilibrium is derived for the second stage of the game, where firms simultaneously choose their prices given their locations. For analytical tractability, we assume the density n_A, n_B to be 1; also, the hybrid firm does not price discriminate across the two channels (i.e., $k = 1$). Both firms and consumers have rational expectations and consumers cannot store the product between periods. Firms choose to maximize total future undiscounted profits. Each consumer purchases one unit of the product in each period and seeks to maximize her net utility over both periods. Firms' Period II choice of prices and profits depend on their Period II demand, which in turn depends on the demand in Period I. We begin by analyzing how the second-period prices and profits depend on the demand in Period I.

Period II. All consumers who purchased a bundle from a particular firm (say firm a) in Period I face identical consumption externalities as well as identical cost of switching to a different firm (within the same channel) in Period II. Each firm maximizes its Period II profits given the prices of the other firms.

Period I. In Period I, while consumers do not enjoy any benefits from network externalities (or are locked in), each firm sets its price while taking into consideration not only the impact on its Period I demand and profitability, but also the effect of its Period I demand on its profitability in Period II. Consequently, a firm chooses its Period I price so as to maximize its total profits over both periods, while taking the prices of other firms in its channel as given. Thus, for instance, in Channel A, firm a chooses p_a^1 so as to maximize its total profits, while taking firm h's price in Period I as given.

$$\pi_a(p_a^1, p_h^1) = \pi_a^1(p_a^1, p_h^1) + \pi_a^2(q_a^1(p_a^1, p_h^1)).$$

At equilibrium we have,

$$\partial \pi_a / \partial p_a^1 = \partial \pi_a^1 / \partial p_a^1 + (\partial \pi_a^2 / \partial q_a^1) \cdot (\partial q_a^1 / \partial p_a^1) = 0.$$

In both cases (network externalities as well as switching costs), we solve for Period I optimal prices and profits for all three firms analytically. Some of the more complex expressions that do not provide additional insights are omitted for the sake of brevity. Detailed mathematical analysis is available upon request.

4.1. Impact of Network Externalities

Proposition 2a. *When the online channel* (*Channel A*) *has positive network externalities, the online, hybrid, as well as the traditional firms compete more intensely in Period I, compared to the base model with no network externalities. Also the firms' Period I prices decrease with increasing network externalities.*

The optimal Period I prices are derived in Appendix B. Rearranging the terms and comparing these prices with the optimal prices in the basic model (with n_A, n_B and $k=1$ in Equations (A.3a) and (A.3c), Appendix A),

$$p_a^1 = \frac{36(p_a^*) - 15\delta_A - 25p_h^1(\delta_A)^2}{36-25(\delta_A)^2};$$

$$p_h^1 = \frac{18(p_h^*) - 3\delta_A - 2p_a^1(\delta_A)^2}{18-2(\delta_A)^2}; \qquad p_b^1 = \tfrac{1}{4}(2p_h^1+1);$$

where

$$p_a^* = \tfrac{1}{4}(2p_h + t_A) \quad \text{and} \quad p_h^* = \frac{t_B(2p_a+t_A)+t_A(2p_b+t_B)}{4(t_A+t_B)}$$

are the optimal prices from the basic model without externalities. The above equations indicate that the Period I prices p_a^1, p_h^1, p_b^1 are lower than their corresponding prices p_a^*, p_h^*, and p_b^* for any positive value of δ_A. Also, as δ_A ($\delta_A \in [0,1]$), the degree of externalities online increases, firm prices decrease.

Proposition 2b. *The optimal Period II prices of both the hybrid firm and the traditional firm are lower in the case with network externalities compared to their corresponding prices in the basic model. Also, their optimal Period II prices decrease with increasing network externalities in the online channel.*

This follows from the optimal Period II prices of firms h and b (refer to Proposition 2a, Appendix B)

$$p_h^2 = p_h^* + \frac{t_B}{(t_A+t_B)}(\delta_A)\left(\frac{1-2q_a^1}{3}\right); \qquad p_b^2 = \tfrac{1}{4}(2p_h^2+t_B).$$

As shown by the proof of Proposition 2a, $q_a^1 > \frac{1}{2}$, making the second term in the above equation for p_h^2 negative. Hence, p_h^2 *and consequently* p_b^2 are lower than their corresponding prices p_h^*, and p_b^* in the basic model. More importantly, as δ_A increases, both p_h^2 and p_b^2 decrease.

Proposition 2c. *The pure play* (*firm a*) *in the channel with higher network externalities is able to increase its prices in Period II compared to its Period I prices. Its Period II prices are also higher than the corresponding price in the basic model. Also, the higher the network externalities, the higher the prices.*

Firm a's optimal Period II price (see Appendix B for detailed analyses) is given by

$$p_a^2 = \tfrac{1}{4}(2p_h^2 + t_A - 2\delta_A + 4\cdot\delta_A\cdot q_a^1).$$

Rearranging the terms and comparing this with firm a's price in the basic model (without network externalities), we have

$$p_a^2 = p_a^* - \delta_A\left(\tfrac{1}{2} - q_a^1\right), \quad \text{where } p_a^* = \tfrac{1}{4}(2p_h + t_A).$$

From Proposition 2a, we know that $p_a^1 < p_a^*$. Because $t_A < t_B$, we have $q_a^1 > q_a^* > \frac{1}{2}$, which implies that $p_a^2 > p_a^*$. It follows that firm a's Period II prices increase with increasing network externalities.

Proposition 2d. *Despite higher prices in Period II, firm a is unable to fully appropriate the additional surplus from the network externalities.*

This follows from the expression for firm a's optimal price in Period II, as in Proposition 2c. Rearranging the terms, we get

$$p_a^2 = p_a^* - \frac{\delta_A}{2} + (\delta_A q_a^1).$$

Here $\delta_A q_a^1$ is the additional utility consumers in Period II gain (from firm a's demand in Period I) due to the presence of network externalities, while p_a^* is firm a's price in the basic model. However, as is evident from the above expression, firm a is unable to fully appropriate this additional surplus, and its Period II price is lower by an amount $\delta_A/2$, which represents the loss from externality-induced competition.

Figures B1–B3 illustrate the impact of increasing network externalities in the online channel on firms' prices and profits. As illustrated in Figure B1, the pure play (firm a) in the channel with higher network externalities prices the lowest in Period I, with the prices decreasing with increasing network externalities in its channel. Correspondingly, its Period I demand increases with increasing network externalities in its channel. While the hybrid firm also prices lower in Period I, its presence in Channel B (with no network externalities) constrains its ability to price lower. Firm b, reacting to firm h, is also forced to lower prices despite the lack of any externalities in its channel.

In Period II, firm a is able to price higher compared to Period I, and this price differential increases with increasing network externalities in its channel. Firm b also prices higher in Period II relative to Period I, but substantially lower than firm a. However, the hybrid firm is constrained in its ability to raise prices significantly in Period II and is unable to fully appropriate the potential gains from externalities in Channel A (see Figure B1). Also, the prices of the hybrid and the traditional firms decrease with increasing externalities in Channel A. Despite higher prices in Period II, the Period II profits as well as the demand of firm *a* increase with increasing network externalities in its channel. This increase in demand for firm *a* comes primarily at the expense of the hybrid firm. The hybrid firm's low price helps it gain a larger market share in the traditional channel. However, with increasing network externalities in the online channel, the hybrid firm loses a *greater* share of its demand in the online channel than it gains in the traditional channel.

While the prices as well as profits of the online pure play (firm *a*) are higher in Period II and increase with increasing network externalities in its channel, the *total* profits (see Figure B2) as well as average prices across both periods (see Figure B3) of all three firms *decrease* with increasing network externalities online. The hybrid firm is the most adversely affected, with its total profits decreasing the fastest with increasing network externalities in Channel A (see Figure B2). Also, the intertemporal prices and profits of the online pure play, firm *a*, exhibit significantly greater volatility than those of its rivals.

4.2. Impact of Switching Costs

Period II. This section analyzes the second period of the market with switching costs after consumers have attached themselves to firms in the first period. The firms' optimal prices are computed as functions of their first-period market shares. Proposition 3a derives the three feasible scenarios.

Proposition 3a. *When consumers switch from one firm to another in Period II, there are three possible cases*:

Case I. *Consumers switch from the pure online firm to the hybrid firm in Period II iff*

$$\left(p_h^1 - p_a^1\right) > \left(p_h^2 - p_a^2\right) + \psi_A.$$

Case II. *Consumers switch from the hybrid firm to the pure online firm in Period II iff*

$$\left(p_h^1 - p_a^1\right) < \left(p_h^2 - p_a^2\right) - \psi_A.$$

Case III. *Consumer do not switch across firms in Period II iff*

$$\left(p_h^2 - p_a^2\right) + \psi_A > \left(p_h^1 - p_a^1\right) > \left(p_h^2 - p_a^2\right) - \psi_A.$$

Corollary 3. *There exists no equilibrium in pure strategies where consumers switch firms in Period II.*

It can be shown that, under certain regularity conditions, firm prices satisfy Case III in Proposition 3a and no consumers switch firms in Period II, at equilibrium. The proof of this proposition sheds no additional insights to the analysis, and hence is omitted. However, the proofs are available upon request.

Proposition 3b. *While the prices and profits of both firms in the online channel with switching costs are lower in Period I, only the online pure play* (*firm a*) *is able to increase its prices and profits in Period II.*

The equilibrium prices and profits are derived in Appendix C. The expressions are better understood through Figures C1 and C2. As with network externalities, switching costs also lead to more intense competition in Period I (see Figure C1). While firms in the (online) channel with switching costs have an incentive to adopt a "loss-leader" pricing strategy to gain a larger market share in Period I, the traditional firm is forced to price lower in Period I, despite no switching costs for consumers in its channel. However, unlike in the case of network externalities, neither the hybrid nor the traditional firm's price changes substantially with increasing switching costs in Channel A (see Figure C1). However, at any given level of switching costs, their lower prices (and profits) in Period I are compensated for by higher prices (and profits) in Period II. The online firm prices the highest in Period II, with its price (and profits) increasing with increasing switching costs online. However, in Period II, the prices (and profits) of the hybrid as well as the traditional firms decrease with increasing switching costs in Channel A (see Figure C1).

Proposition 3c. *The total profits and price of the online firm a* (*across both periods*) *increase with increasing switching costs in the online Channel A*.

Figures C2 and C3 illustrate the impact of increasing switching costs in Channel A on firms' total profits and average prices. Contrary to the case of network externalities, the *average* price (across both periods) charged by the online firm, as well as its *total* profits, increase with increasing switching costs online. Also, the average price charged by the online firm is the highest, while that of the hybrid firm is the lowest.

4.3. Comparison of Equilibria and Consumer Welfare

As noted earlier, comparing the basic model, where the hybrid firm is restricted in its ability to price discriminate across the two channels, with the case where the hybrid firm is free to price discriminate, shows that total consumer welfare is the higher in the former compared to the latter.

When the network externalities are higher online relative to the traditional channel, the *average* prices (as well as total profits) of all firms decrease with increasing network externalities (see Figures B2 and B3). This is despite all three firms being able to charge a higher price in Period II relative to their Period I prices. Moreover, network externalities in one channel make *both* the channels more competitive. The results indicate that while consumers in the online channel clearly benefit from the positive consumption externalities enabled by the channel, consumers in the traditional channel also benefit, irrespective of which firm they purchase from. In contrast, in the case of markets with switching costs, while average price (across both periods) charged by the online firm, as well as its total profits increase, with increasing switching costs, the average prices as well as total profits of both the traditional as well as the hybrid firm decrease (see Figures C2 and C3). Given that at equilibrium no consumer switches firms in Period II, total consumer surplus decreases with increasing switching costs in the online channel, A.

Both network externalities and switching costs intensify price competition in the initial periods and enable firms to price higher in the later periods. However, higher positive externalities result in lower average prices and lower total profits for all firms as the resultant competitive effects outweigh surplus extraction abilities of firms. Consumers benefit disproportionately—in addition to the direct benefits from positive externalities that the channel facilitates, they also benefit from the resulting price competition. Firms in channels with network externalities, are locked in a "prisoner's dilemma" and are unable to appropriate the benefits from the externalities. However, in the case of switching costs, the pure play in the channel with higher switching costs gains at the expense of its hybrid and traditional rivals. Thus, while the online pure-plays' consumers always benefit from higher levels of network externalities in their channel, the firm itself benefits only if it is able to increase switching costs for consumers in its channel.

5. Managerial Implications and Conclusions

The emergence of channels such as the Web and mobile devices portends significant changes in the competitive landscape for traditional firms. The features offered by new technology-driven channels not only add value, but also enhance channel flexibility, thereby reducing firms' ability to differentiate themselves, and intensifying competition. This generally lowers firm profits and benefits consumers in these channels. However, the hybrid firm serves as a moderating force—reducing the competitive intensity of the more flexible channel while increasing that of the less flexible one. This is of particular significance for studies examining the "efficiency" of emerging technological channels that coexist with traditional ones.

In addition to channel flexibility, asymmetries in network externalities and switching costs also have significant implications for the business models and pricing strategies of firms competing across differentiated channels. While high levels of network externalities and switching costs online can lead to "winner-take-all" outcomes, we find that a large market share does not always translate into high profits for these firms. This may be an important reason why several online firms adopt business models that seek alternate revenue streams, namely, advertising revenues and affiliate marketing, in addition to revenues from direct sales of products and services. Also, cross-selling strategies that leverage consumer information, to provide value across different markets, become critical for a firm's success.

Our results highlight the importance of trade-offs between investments in features that generate network externalities and those that lock in consumers. Firms like Amazon.com have made significant investments in recommendation systems, reviews and ratings, and online communities—features that generate network externalities. While these investments may lead to a higher market share, they do not necessarily imply higher profits for these firms. Unless these features help firms to lock in consumers, these investments become *strategic necessities*, with the benefits being dissipated by increased competition.

Our analysis also generates significant implications for firms grappling with issues of channel choice and configuration as well as issues of integration and divestiture. Figures D1 and D2 illustrate the regions where a particular pure-play or hybrid strategy dominates the others. As indicated in these figures, when the online channel has high flexibility *but* a low ability to lock in consumers *or* benefit from network externalities, a firm benefits by being a traditional pure play rather than being a hybrid. As the network externalities (see Figure D1) as well as the ability to lock in consumers (see Figure D2) online increase, a hybrid strategy becomes increasingly attractive. However, when the benefits from externalities and "consumer lock-in" features of the online channel are sufficiently high, an Internet pure-play strategy dominates the others. The video-gaming industry is currently dominated by stand-alone console games. However, traditional firms like Sony, Nintendo, and Microsoft are rapidly moving online to create multiplayer versions to leverage the significant network externalities that the online channel facilitates. Unlike stand-alone games, the success of multiplayer online games largely depends on their ability to create and sustain a large community of users. As indicated by

Figures D1 and D2, given the high network externalities and switching costs for online games, it is highly likely that online games will dominate traditional ones.

Another important issue concerning firm structure is whether to integrate or spin off firms' online operations. It is easy to see from Figures B2 and C2 that the total profits of the combined (offline and online) units are significantly higher than that of an integrated hybrid firm. This implies that when the two channels differ substantially in their ability to generate network externalities or create lock-in, traditional firms benefit from spinning off their online divisions and adopting independent pricing and positioning strategies, rather than being a tightly integrated hybrid with similar pricing and positioning strategies across the two channels. More generally, when the two channels differ substantially in any of the key channel parameters, firms benefit by segmenting customers based on their channel preferences and choosing their positioning and pricing strategies accordingly. These findings are of particular significance to traditional firms with strong offline brands, as they would need to carefully balance the benefits of extending their brand equity online with the costs of adopting integrated strategies across the two channels.

To sum up, given the strategic spillovers across technology-differentiated channels, any analysis that focuses on competition between firms in a single channel in isolation would be inadequate and even potentially misleading. Firms faced with new technological channels will need to reexamine their existing value propositions, taking into account the interactions across channel boundaries, and design strategies that best exploit the differences between them.

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Appendix A. The Basic Model

Proof of Proposition 1a. Because the firms are located diametrically opposite each other in their own channels, we derive the optimal prices for the firms, given their locations. Firms choose their prices simultaneously, given their locations.

Equilibrium. Let firms a and b be located at a distance $y_a = \frac{1}{2}$ and $y_b = \frac{1}{2}$ from firm h. A consumer situated at a distance x from firm a (between firm a and firm h) in Channel A (see Figure 1) purchases from firm a if $p_a + t_A x \leq p_h + t_A(\frac{1}{2} - x)$, or if

$$x \leq \frac{2(p_h - p_a) + t_A}{4t_A}.$$

Figure A1 Optimal Prices with Varying Online Channel Misfit Costs

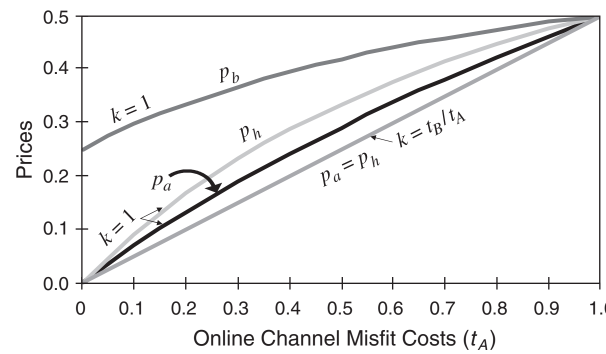


Figure A2 Optimal Profits with Varying Online Channel Misfit Costs

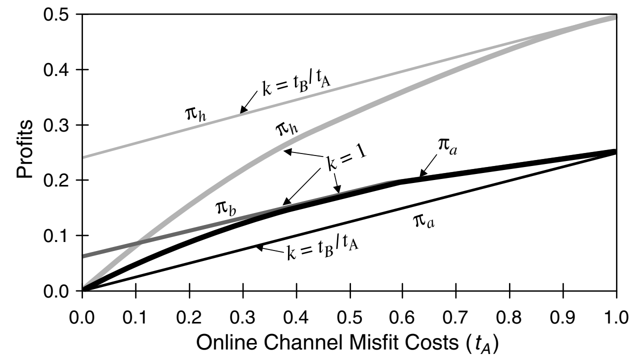
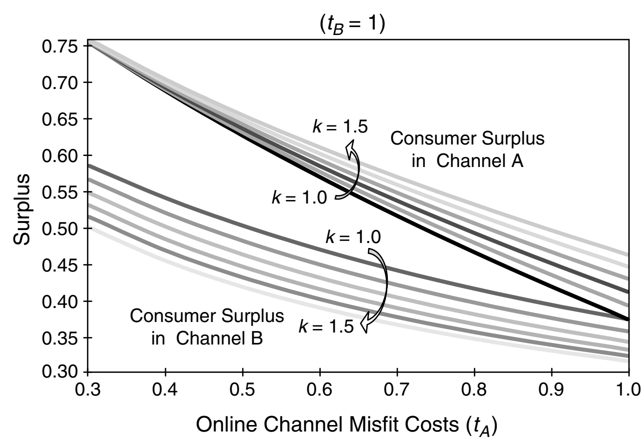


Figure A3 Consumer Surplus



The total demand faced by firm a in market A is, therefore,

$$q_a = 2q_{a1} = n_A\left(\frac{2(p_h - p_a)}{2t_A} + \frac{1}{2}\right).$$

Similarly, the demand for Firm B in Channel B (given, hybrid firm's price kp_h in Channel B) is

$$q_b = n_B\left(\frac{2(kp_h - p_b)}{2t_B} + \frac{1}{2}\right).$$

Firm h has a presence in both markets. Given the assumptions about consumer reservation prices and that each consumer purchases from exactly one of the three firms, the total demand for firm h is simply $(n_A - q_a) + (n_B - q_b)$, which simplifies to

$$q_h = n_A\left(\frac{1}{2} + \frac{2(p_a - p_h)}{2t_A}\right) + n_B\left(\frac{1}{2} + \frac{2(p_b - kp_h)}{2t_B}\right).$$

Given the prices p_a, p_b, and p_h, the profits for the three firms are therefore:

$$\pi_a = p_a n_A\left(\frac{2(p_h - p_a)}{2t_A} + \frac{1}{2}\right), \tag{A.1a}$$

$$\pi_b = p_b n_B\left(\frac{2(kp_h - p_b)}{2t_B} + \frac{1}{2}\right), \tag{A.1b}$$

$$\pi_h = p_h n_A\left(\frac{1}{2} + \frac{2(p_a - p_h)}{2t_A}\right) + kp_h n_B\left(\frac{1}{2} + \frac{2(p_b - kp_h)}{2t_B}\right). \tag{A.1c}$$

At equilibrium, each firm i chooses price p_i to maximize its profits, given the price choices of the other firms. Solving the price reaction functions (see Equations (1.1) to (1.3)) implied by the first-order conditions yields the following equilibrium prices:

$$p_a^* = \frac{t_A[2n_A t_B + kn_B(kt_A + t_B)]}{4[k^2 n_B t_A + n_A t_B]};$$

$$p_b^* = \frac{t_B[2k^2 n_B t_A + n_A(kt_A + t_B)]}{4[k^2 n_B t_A + n_A t_B]}; \qquad p_h^* = \frac{t_A t_B(n_A + kn_B)}{2[k^2 n_B t_A + n_A t_B]}.$$

It is easily verified from the second derivatives that each firm's profit function is strictly concave in its own price (for positive t_i). This concludes the proof. □

Proof of Proposition 1b. The profit functions can be obtained by direct substitution. □

Proof of Corollary 1. In this case, because firm h also chooses k, solving for the four first-order conditions (three with respect to prices and one with respect to k) yields, in addition to the three reaction functions (A.1a)–(A.1c), $k = (2p_b + t_B)/(4p_h)$. Solving, we have, $p_a^* = t_A/2$; $p_b^* = t_B/2$; $p_h^* = t_A/2$; $k^* = t_B/t_A$. The prices of the three firms are dependent on just their channel misfit costs, but independent of each other. This concludes the proof. □

Proof of Corollary 2. When the two channels are independent, the profit of the pure play in the channel with higher flexibility (i.e., lower misfit costs, say, Channel A) is $\pi_a = n_A t_A/4$. Rewriting firm a's profits from Equation (1.4) (for the case where the value of k is restricted, i.e., $k < t_B/t_A$), we have,

$$\pi_a^* = \frac{n_A t_A}{4}\left(\frac{2n_A t_B + k^2 n_B(t_A + t_B)}{2(k^2 n_B t_A + n_A t_B)}\right)^2.$$

Because $kt_A < t_B$, the term inside the parentheses is greater than 1, and hence π_a^* is greater than $n_A t_A/4$. □

Appendix B. Impact of Network Externalities

Proof of Proposition 2a. As a reminder, p_i^k, q_i^k, and π_i^k are the price, demand, and profit, respectively, for firm i in period k. As described in §4.1, the value from network externalities to firm a's consumer in Period II is $\delta_A q_a^1$. The utility for a consumer in Channel A, who purchases a bundle from firm a at price p_a^2, located at a distance x is given by $U_i = \check{r} - p_a^2 - t_A(x) + \delta_A q_a^1$

In Channel A, q_a^2 is the demand faced by firm a in Period II and q_{hA}^2 is the market share of firm h in Channel A in Period II. So, in Period II (assuming $n_A = n_B = 1$, and $k = 1$), based on the indifferent consumer, the total demand for firm a is given by

$$q_a^2 = \frac{2(p_h^2 - p_a^2) + t_A - 2\delta_A + 4\delta_A q_a^1}{2t_A}.$$

Because there are no network externalities in the traditional channel (Channel B), the total demand for firm b and firm h in Period II are:

$$q_b^2 = \frac{2(p_h^2 - p_b^2) + t_B}{2t_B};$$

$$q_h^2 = \frac{2(p_a^2 - p_h^2) + t_A - 2\delta_A + 4\delta_A q_{ha}^1}{2t_A} + \frac{2(p_b^2 - p_h^2) + t_B}{2t_B}.$$

Each firm maximizes its Period II profits given the prices of other firms in Period II as well as in Period I. F.O.C yield,

$$p_a^2 = \tfrac{1}{4}(2p_h^2 + t_A - 2\delta_A + 4\delta_A q_a^1); \qquad p_b^2 = \tfrac{1}{4}(2p_h^2 + t_B);$$

$$p_h^2 = \frac{(2p_b^2 t_A + 2p_a^2 t_B + 2t_A t_B + 2t_B\delta_A - 4\delta_A t_B q_a^1)}{4(t_A + t_B)}.$$

Optimal Prices: Period I. There are no positive consumption externalities in Period I, and the total demand for

Figure B1 Optimal Intertemporal Prices with Network Externalities

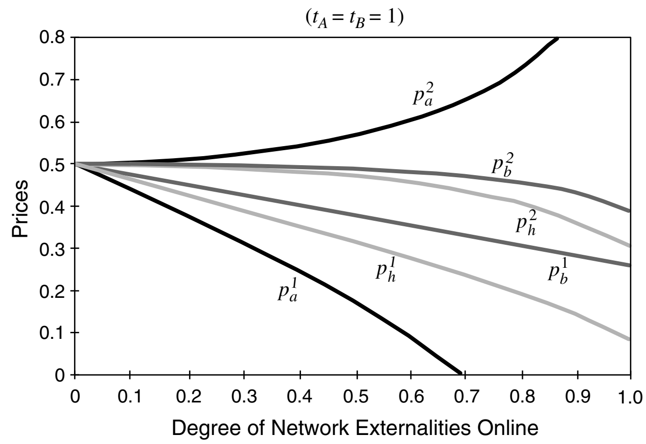


Figure B2 Total Profits with Network Externalities

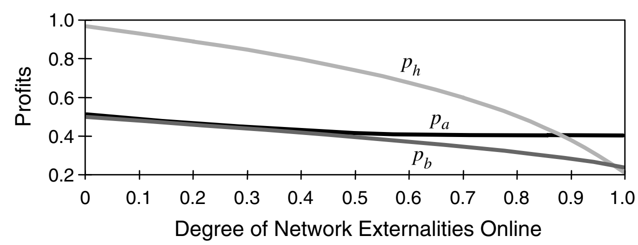
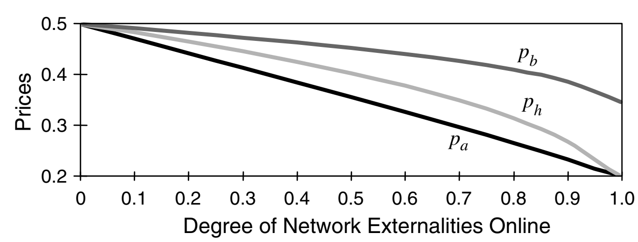


Figure B3 Average Prices with Network Externalities



firms a, b, and h in Period I are given by

$$q_a^1 = \frac{2(p_h^1 - p_a^1) + t_A}{2t_A}; \qquad q_b^1 = \frac{2(p_h^1 - p_b^1) + t_B}{2t_B};$$
$$q_h^1 = \frac{2(p_a^1 - p_h^1) + t_A}{2t_A} + \frac{2(p_b^1 - p_h^1) + t_B}{2t_B}.$$

Firm a chooses p_a^1 so as to maximize its total future profits, while taking firm h's price in Period I as given.

$$\pi_a(p_a^1, p_h^1) = \pi_a^1(p_a^1, p_h^1) + \pi_a^2(q_a^1(p_a^1, p_h^1)).$$

Profits for firms a, b, and h in Period I are given by

$$\pi_a^1 = \frac{2(p_h^1 - p_a^1) + t_A}{2t_A} \times p_a^1; \qquad \pi_b^1 = \frac{2(p_h^1 - p_b^1) + t_B}{2t_B} \times p_b^1;$$
$$\pi_h^1 = \left(\frac{2(p_a^1 - p_h^1) + t_A}{2t_A} + \frac{2(p_b^1 - p_h^1) + t_B}{2t_B}\right) \times p_h^1.$$

F.O.C yield,

$$\begin{aligned} p_a^1 = {} & \frac{1}{36(t_A)^2(t_A+t_B)^2 - 4(3t_A+2t_B)^2(\delta_A)^2} \\ & \cdot\big[9t_A^2(2p_h^1+t_A)(t_A+t_B)^2 - 3(t_A)^2(3t_A+2t_B)(t_A+3t_B)\delta_A \\ & - 4p_h^1(3t_A+2t_B)^2(\delta_A)^2\big] \\ p_h^1 = {} & \frac{1}{18(t_A)^2(t_A+t_B)^2 - 8(t_B)^2(\delta_A)^2} \\ & \cdot\big[9(t_A)^2(t_A+t_B)((p_b^1)t_A + (p_a^1+t_A)t_B) \\ & - 12(t_A)^2(t_B)^2\delta_A - 8p_a^1(t_B)^2(\delta_A)^2\big] \end{aligned}$$

Because there are no externalities in the traditional Channel B, the optimal Period I prices for firm b is dependent only on firm h's optimal Period I prices, and is given by $p_b^1 = \frac{1}{4}(2p_h^1 + t_B)$. □

Proof of Proposition 2b. Solving for q_a^1 and q_{ha}^1, and substituting these into the expressions (from Proposition 2a) for p_a^2, p_b^2, and p_h^2, gives the following unique profit-maximizing equilibrium prices in Period II.

$$p_a^2 = \frac{3t_A(t_A+3t_B) + 2((3t_A+2t_B)(-1+2q_a^1))\delta_A}{12(t_A+t_B)};$$
$$p_b^2 = \frac{t_B(9t_A+3t_B+(2-4q_a^1)\delta_A)}{12(t_A+t_B)};$$
$$p_h^2 = \frac{t_B(6t_A+(2-4q_a^1)\delta_A)}{6(t_A+t_B)}. \quad \square$$

Appendix C. Impact of Switching Costs

Proof of Proposition 3a.

Proof of Case I. From Proposition 1a, we know $q_a^1 = (2(p_h^1 - p_a^1) + t_A)/2t_A$. However, in Period II, a consumer who initially purchased a bundle from firm a in Period I and wishes to switch to firm h in Period II, faces an additional switching cost ψ_A. Thus, in Period II, a consumer will purchase from firm a iff, $p_a^2 + t_A x \le p_h^2 + t_A(0.5 - x) + \psi_A$.

Therefore, total demand for firm a in Period II is given by

$$q_a^2 = \frac{2(p_h^2 - p_a^2) + t_A + 2\psi_A}{2t_A}.$$

From the expressions above, $q_a^1 > q_a^2$ implies $(p_h^1 - p_a^1) > (p_h^2 - p_a^2) + \psi_A$. Hence, the proof. □

Proof of Case II. Similar to Case I. □

Proof of Case III. Follows trivially from Cases I and II. □

Proofs of Proposition 3c and 3d. q_a^2 is the demand faced by firm a in Period II in Channel A and q_{ha}^2 is the Period II demand for firm h in Channel A. Proposition 3b yields $q_a^2 = q_a^1$; and $q_{ha}^2 = q_{ha}^1$.

In Channel B,

$$q_b^2 = \frac{2(p_h^1 - p_b^1) + t_B}{2t_B} \quad \text{and} \quad q_{hb}^2 = \frac{2(p_b^2 - p_h^2) + t_B}{2t_B}.$$

Therefore, the *total* demand for firm h in Period II is given by

$$q_h = q_{ha}^1 + \frac{2(p_b^2 - p_h^2) + t_B}{2t_B}.$$

Profits for firms a, b, and h in Period II are given by

$$\pi_a^2 = q_a^1 \times p_a^2; \qquad \pi_b^2 = \frac{2(p_h^2 - p_b^2) + t_B}{2t_B} \times p_b^2;$$
$$\pi_h^2 = \left(q_{ha}^1 + \frac{2(p_b^2 - p_h^2) + t_B}{2t_B}\right) \times p_h^2.$$

First-order conditions[4] yield

$$p_a^2 = (p_a^1 - p_h^1) + \tfrac{1}{6}(7 - 4q_a^1)t_B + \psi_A; \qquad p_b^2 = \tfrac{1}{6}(5 - 2q_a^1)t_B;$$
$$p_h^2 = \tfrac{1}{6}(7 - 4q_a^1)t_B + \psi_A.$$

In Period I, consumers are not locked in to any firm and do not face any switching costs. Hence, the total demand for firms a, b, and h in Period I are given by

$$q_a^1 = \frac{2(p_h^1 - p_a^1) + t_A}{2t_A}; \qquad q_b^1 = \frac{2(p_h^1 - p_b^1) + t_B}{2t_B};$$
$$q_h^1 = \frac{2(p_a^1 - p_h^1) + t_A}{2t_A} + \frac{2(p_b^1 - p_h^1) + t_B}{2t_B}.$$

Firms seek to maximize the total undiscounted profits over both periods. Firm a chooses p_a^1 taking firm h's price in Period I as given. So, $\pi_a(p_a^1, p_h^1) = \pi_a^1(p_a^1, p_h^1) + \pi_a^2(q_a^1(p_a^1, p_h^1))$. Profits for firms a, b, and h in Period I are given by

$$\pi_a^1 = \frac{2(p_h^1 - p_a^1) + t_A}{2t_A} \times p_a^1; \qquad \pi_b^1 = \frac{2(p_h^1 - p_b^1) + t_B}{2t_B} \times p_b^1;$$
$$\pi_h^1 = \left(\frac{2(p_a^1 - p_h^1) + t_A}{2t_A} + \frac{2(p_b^1 - p_h^1) + t_B}{2t_B}\right) \times p_h^1.$$

First-order conditions yield

$$p_a^1 = \frac{18p_h^1 t_A + 6(t_A)^2 + 8p_h^1 t_B - 3t_A t_B - 6t_A\varphi_A}{8(3t_A + t_B)};$$
$$p_b^1 = \tfrac{1}{4}(2p_h^1 + t_B);$$
$$p_h^1 = \frac{9p_b^1(t_A)^2 + 9p_a^1 t_A t_B + 9(t_A)^2 t_B - 8p_a^1(t_B)^2 - 10(t_B)^2 t_A}{2(9(t_A)^2 + 9t_A t_B - 4(t_B)^2)}.$$

[4] The optimal prices for firm a are not defined, and hence are bounded by the constraint.

Figure C1 Optimal Intertemporal Prices with Switching Costs

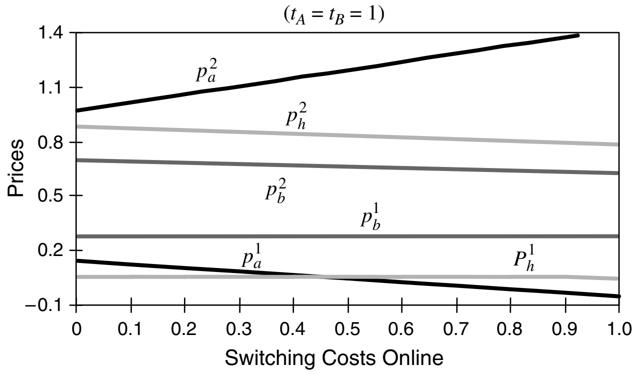


Figure C2 Total Firm Profits with Switching Costs

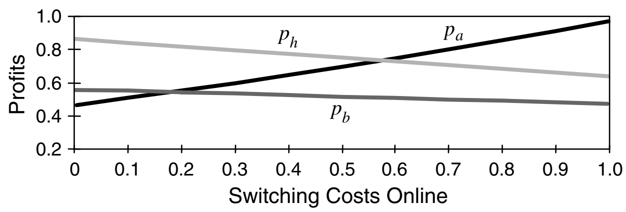


Figure C3 Average Firm Prices with Switching Costs

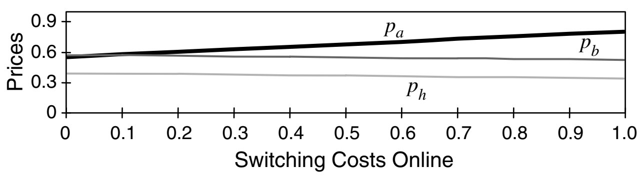


Figure D1 Zone of Dominance (Externalities in the Online Channel; $t_A = 1$)

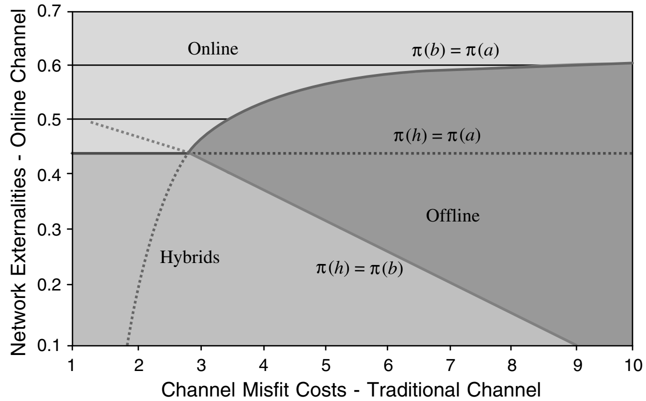
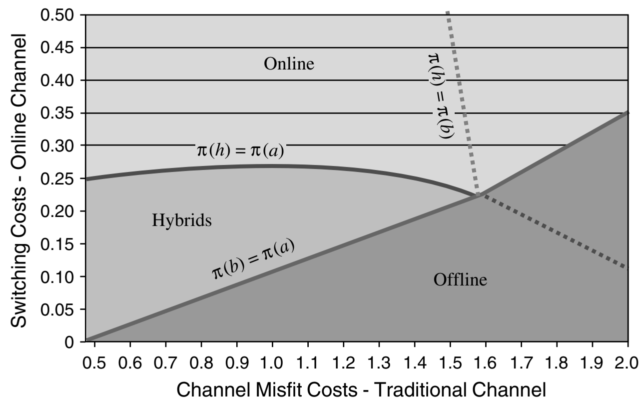


Figure D2 Zone of Dominance (Switching Costs in the Online Channel; $t_A = 1$)



Solving the above expressions yields

$$
\begin{aligned}
p_a^1 &= \frac{1}{6\big(54(t_A)^2 + 63t_At_B + 4(t_A)^2\big)}\\
&\quad \cdot \big[81(t_A)^3 + 27(t_A)^2(10t_B - 3\psi_A)\\
&\quad - 12t_At_B(16t_B + 9\psi_A) + 8(t_B)^2(6\psi_A - 7t_B)\big];\\
p_b^1 &= \frac{t_B\big(243(t_A)^2 - 22(t_B)^2 + 24t_B\psi_A - 9t_A(2t_B + 3\psi_A)\big)}{6\big(54(t_A)^2 + 63t_At_B + 4(t_B)^2\big)};\\
p_h^1 &= \frac{t_B\big(9t_A - 8t_B\big)(36t_A + 7t_B - 6\psi_A\big)}{6\big(54(t_A)^2 + 63t_At_B + 4(t_B)^2\big)}.
\end{aligned}
$$

Solving for q_a^1, q_{ha}^1 and substituting these expressions into p_a^2, p_b^2, and p_h^2 yields

$$
\begin{aligned}
p_a^2 &= \frac{1}{2\big(54(t_A)^2 + 63t_At_B + 4(t_B)^2\big)}\\
&\quad \cdot \big[27(t_A)^3 + 2(t_B)^2(7t_B - 2\psi_A)\\
&\quad + 9(t_A)^2(10t_B + 9\psi_A) + 2t_At_B(52t_B + 45\psi_A)\big];\\
p_b^2 &= \frac{3t_B\big(27(t_A)^2 + t_A(26t_B - 3\psi_A) + t_B(3t_B - 2\psi_A)\big)}{2\big(54(t_A)^2 + 63t_At_B + 4(t_B)^2\big)};\\
p_h^2 &= \frac{t_B(3t_A + 2t_B)(36t_A + 7t_B - 6\psi_A)}{2\big(54(t_A)^2 + 63t_At_B + 4(t_B)^2\big)}. \quad \square
\end{aligned}
$$

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