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Abstract

Firms in information technology (IT) intensive industries rely on IT investments to improve the quality of their products and services. Competing firms in these industries need to consider two opposing effects when they make IT investment decisions. The declining cost and improving performance of IT over time provides the later entrant a potential cost advantage. On the other hand, the first entrant has the potential to build its market share and retain the market share if consumers incur a cost to switch to the later entrant. In this paper, we analyze the investment strategy of an early entrant that expects the later entrant to have a cost advantage. The results show that in a market with a low (high) switching cost, a decline in IT cost reduces (increases) the investment level of the early entrant. In both types of markets, a higher switching cost mitigates the cost advantage of the later entrant. The results suggest that the early entrant should design a product that imposes a high switching cost. We use examples from Internet Service Providers to provide the motivation for the problem and illustrate the model, analysis, and results.

1 INTRODUCTION

Expenditures on information technology (IT) are a significant portion of corporate budgets worldwide. *The 2000 Gartner IT Spending and Staffing Survey* stated that leading edge adopters of technology spend 11 percent of their revenue on IT while it is 3 percent for conservative technology spenders (Brune 2000). Expenditure on IT infrastructure takes up more than half of a firm's IT budget. A study of IT investment patterns by Weill and Broadbent (1998) revealed that firms spent 58 percent of their total IT investments on infrastructure. IT intensive firms spent even more, 65 percent, of their total IT investments on infrastructure.

Firms, especially those in IT intensive industries such as financial services, banking, and telecommunications, rely on IT investments to improve the quality of their products and services. For example, consider Internet Service Providers (ISPs). An ISP can improve the quality of the Internet connection it offers to its subscribers by investing heavily in IT infrastructure. ISPs' investments in IT infrastructure typically are in media bandwidth, Ethernet switches, remote access, and local servers. The quality of the Internet connection is measured by various metrics such as average time to log on, average download time, and average Web throughput (*Network World*, September 2001). Higher bandwidth and higher capacity switches and servers provide a higher connection quality on these dimensions. Higher bandwidth and server capacity require higher investment in IT infrastructure.

An important characteristic of IT is that the cost of IT declines and performance improves over time. Moore's Law states that computers either double in power for the same cost or halve in cost for the same power every 18 months. The price of computers, adjusted for computing power, decreased at a 34 percent annual rate during the second half of 2001 (Mandel 2001). Similarly, between 1994 and 1998, the carrying capacity of fiber doubled every year, and the price of telecommunication equipment declined by 2 percent every year (Mandel 2000).

Numerous business models ascribe a “first-mover advantage” and a “winner-take-all” outcome for the first firm, especially in high-technology industries. The rationale for such attributions includes switching costs, network effects, brand recognition, and the first firm’s opportunity to set standards (Lieberman and Montgomery 1988). These may provide powerful incentives for the first-mover to over-invest. However, in contrast to these early mover advantages, pioneers may incur a cost disadvantage in IT-intensive industries. As a result, competition from a later entrant with a cost advantage may jeopardize the position of the early entrant. A study conducted by Boulding and Christen (2001) revealed that even in the traditional consumer goods (industrial goods) sector, pioneers’ return was 3.78 percent (4.24 percent) lower than that of later entrants because of the cost disadvantage. Numerous examples have also been reported in popular press on how the cost advantage of later entrants negatively affects the early entrants. In the digital subscriber line (DSL) market, the Baby Bells, a late entrant to the market, took advantage of as much as 40 percent price declines in DSL equipment in 2001, whereas the upstart DSL companies such as North Point Communications Inc. and Covad Communications Group Inc. had already invested in older, more expensive technologies (John 2000). Additionally, new technologies that allowed consumers to automatically set up the services themselves significantly lowered the cost of DSL installation for the Bells (Black 2001). The lower equipment and installation costs allowed the Bells to offer higher quality services.

The above examples illustrate that the first-mover advantage of the firms that enter the market early may be weakened when technological advances over time favor the firms that enter the market later. The early entrants may actually enjoy some advantages because of switching costs incurred by consumers. In the ISP market, statistics show that the average customer turnover ranges from 6 to 9 percent which means that the majority of new subscribers come from other ISPs (Martorelli 2000). In other words, consumers have rather low switching costs in the ISP market. Faced with this challenge, in addition to Internet access services, ISPs are seeking to provide proprietary content and value-added services including e-mail, instant messaging, Web hosting, and content filtering to subscribers. These additional services impose switching costs on consumers. The switching costs in the ISP market include the learning required to use the new interface or software, the costs of changing the e-mail, and restrictions on the use of certain features between subscribers of different ISPs such as the instant messenger features of AOL and MSN. The interplay of switching costs and declining technology costs makes deciding the IT investment strategies challenging.

We study the problem of strategic IT investments when firms that enter the market at different times face different costs, and consumers face switching costs using a duopoly model. We find that the presence of a switching cost favors the early entrant in general even when a decline in technology cost favors the later entrant. There is, nevertheless, no guarantee that a positive switching cost will be sufficient to ensure a strong position for the first-mover in the presence of declining technology costs. The results show that in a market with low (high) switching cost, a higher decline in IT cost reduces (increases) the investment level of the early entrant more. In both types of markets, a higher switching cost mitigates the cost advantage of the later entrant. In a market characterized by high switching costs, the first entrant is able to sustain its first-mover advantage when the switching cost is above a threshold.

The rest of this paper is structured as follows: In section 2, we review the relevant literature and discuss how our work complements the existing literature. In section 3, we describe the basic model. In sections 4 and 5, we present our principal analytical results. In section 6, we discuss the managerial implications of the results and the limitations of the model.

2 LITERATURE REVIEW

Information technology has long been considered a crucial factor that creates sustained competitive advantage for firms (Barney 1991; Clemons 1991). Consequently, investment in information technology has become a strategic decision for firms. These developments have led to several studies that investigated strategic IT investments in a competitive scenario using analytical models. Many of these studies considered simultaneous decision models (e.g., Banker et al. 1998; Kim et al. 2000) and did not address the effect of decline in IT cost over time. For example, Kim et al. (2000) examined the trade-offs between IT investments in quality and pricing of the services. They found that lower technology prices lead to higher quality together with higher prices. In a study closely related to our work, Barua et al. (1991) analyzed how firms’ relative IT efficiencies influence their strategic IT investments by considering sequential entry. However, different from our model, in their model, price was considered exogenous and independent of quality, that is, consumers base their decision to choose the product only on the quality. The goal of their paper was to analyze the timing of IT investments given that technology is available. They found that firms prefer to make sequential instead of simultaneous investment decisions, the firm that has a cost disadvantage prefers to be the follower, and the firm that has a cost advantage prefers to be the leader only when its cost advantage is significant.

Strategic management, marketing, and economics scholars have also studied the issue of first-mover advantages and disadvantages. Most of these papers provided empirical evidence using market share and sales data (Mascarenhas 1992; Robinson et al. 1994; Tufano 1989; Urban et al. 1986). There is, nevertheless, no guarantee that these potential advantages of early entrant will provide a strong position to the pioneers. In fact, there exist various first-mover disadvantages that can negate the benefits of early entry, such as a late entrant's ability to free ride on first-mover investments, resolution of technological and market uncertainty favoring the late movers, and technological discontinuities (Lieberman and Montgomery 1988).

The studies in the economics literature considered the price competition between an early entrant and a late entrant (e.g., Beggs and Klemperer 1992; Farrell and Shapiro 1988; Klemperer 1987a, 1987b; Nilssen 1992; von Weizsacker 1984). They analyzed how the switching costs affect prices and social welfare. These studies assumed that the quality levels are exogenously given and are identical across firms.

The problem we consider is different from those addressed in papers cited above in the sense that, in our model, the later entrant has a cost advantage but the early entrant has an advantage in the form of a consumer switching cost. Also, the demand is dependent not only on the price but also on product quality, which depends on investment level. Unlike previous work, we are interested in how the extent of decline in technology cost and the level of switching cost affect firms' investment decisions and profits.

3 BASIC MODEL

We consider two firms, labeled as 1 and 2 in a two-period model. Limitations of duopoly model and possible research issues for oligopoly model are discussed in section 6. Without loss of generality, we assume that firm 1 enters the market first in period 1 and firm 2 enters the market next in period 2. Each firm offers a single product or service. The relevant characteristics of the product used by consumers to make their purchase decisions are modeled along two dimensions, quality and content. For example, in the ISP example, quality is defined by characteristics such as connection speed, and content is defined by available services such as e-mail, Web hosting, and customer support. Every consumer prefers higher to lower quality, but the consumers differ with respect to their preferences on the content dimension. The quality level of a product is dependent on the firm's investment in technology. Higher quality requires a higher investment. The specific assumptions of our model are as follows.

1. The sequence of actions taken by the two firms is as follows:
   a. In period 1, firm 1 makes the investment in technology and chooses its quality level k_1 and its price for period 1, p_{11}.
   b. In period 2, firm 2 makes its investment in technology and chooses its quality level k_2 after observing k_1.
   c. Firm 1 and firm 2 set their prices for period 2, p_{12} and p_{22} respectively, simultaneously after observing each other's quality.

2. The investments once made are sunk costs that cannot be changed. In other words, the technology chosen by the firm cannot be changed during the two periods because it is very costly for firm 1 to abandon its current technology and adopt the better technology available in period 2.[1]

3 The functions that relate investments C_1 and C_2 of firm 1 and firm 2 respectively to their quality levels are:

$$C_1 = \frac{k_1^2}{2} \qquad\qquad C_2 = \delta \frac{k_2^2}{2}$$

We assume a quadratic total cost structure. This assumption may be defended on the ground that it is necessary to capture the property that cost increases with quality at a faster rate than any consumer's willingness to pay. Thus, investing in technology becomes increasingly difficult as the quality level increases. We assume that $\delta < 1$ to model the declining cost

[1]The alternative is to assume that firm 1 can adopt new technology. In this case, our model reduces to one with simultaneous investments rather than sequential investments. The focus of this paper, however, is only on sequential investments.

of investments. It is also assumed, for simplicity, that the marginal cost of production as well as other fixed costs are zero for each firm in order to focus on the impact of declining technology costs.

4. The content dimension of the product is modeled using parameter x. There are N consumers whose preferences differ along this dimension. We assume that their preferences are distributed uniformly on the line [0,1]. Consumers incur a utility loss t per unit distance between their ideal preference location and the location of the product they purchase. Firms locate their products at the opposite ends of the line.

5 Consumers who switch from firm 1 in period 1 to firm 2 in period 2 incur a switching cost s

6. Let firm 1 serve the consumers located to the left of x_0 (Figure 1). The utility of a consumer located at $x < x_0$ for period 1 is assumed to be $\theta_1 k_1 - p_{11} - tx$, where $\theta_1 > 0$ is the consumers' utility per unit quality of product 1.

   Let firm 2 serve consumers located to the right of $x_1 < x_0$ and firm 1 serve consumers located to the left of x_1 in the second period.[2] The utility of a consumer located at $x < x_0$ in period 2 is $\theta_1 k_1 - p_{12} - tx$. The utility of a consumer located at $x > x_1$ in period 2 is $\theta_2 k_2 - p_{22} - t(1-x) - s$, where $\theta_2 > 0$ is the consumers' utility per unit quality of product 2.

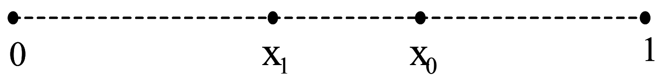

Figure 1. Consumer Preference Line

4 ANALYSIS

We are primarily interested in determining the impact of s and δ on quality levels and profits. We look for the sub-game perfect Nash equilibrium and obtain the results by backward induction.

4.1 Period II Decisions

We first solve for the prices in terms of unknown qualities and then solve for the qualities.

4.1.1.Price Equilibrium

The location of the marginal customer x_1 (Figure1) who is indifferent between buying from firm 1 and firm 2 in period 2 is given by:

$$x_1 = \frac{t + s + \theta_1 k_1 - p_{12} + p_{22} - \theta_2 k_2}{2t} \tag{1}$$

The location of the marginal customer shifts to the right as the switching cost increases, i.e., $\frac{\partial x_1}{\partial s} > 0$. With a high switching cost, the number of customers firm 1 (firm 2) serves increases (decreases). Similarly, the demand for firm 1 in period 2 is increasing in k_1 and p_{22} and decreasing in k_2 and p_{12}, i.e., $\frac{\partial x_1}{\partial k_1} > 0, \frac{\partial x_1}{\partial p_{22}} > 0, \frac{\partial x_1}{\partial k_2} < 0 \; and \; \frac{\partial x_1}{\partial p_{12}} < 0$. The revenue functions of firm1 and firm 2 in period 2are given by $R_{12} = N x_1 p_{12}$ and $R_{22} = N(1 - x_1)p_{22}$.

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[2]We assume $x_1 < x_0$ so that there will be some switchers. In the absence of this assumption, switching cost has no impact on firms' decisions.

Both firms choose their prices simultaneously to maximize their revenue given the quality levels. Solving the first order conditions for the equilibrium prices simultaneously, we obtain the following prices:

$$p_{12}^{*} = \frac{3t + s + \theta_1 k_1 - \theta_2 k_2}{3} \tag{2}$$

$$p_{22}^{*} = \frac{3t - s - \theta_1 k_1 + \theta_2 k_2}{3} \tag{3}$$

Since $\frac{\partial^2 R_{12}}{\partial (p_{12})^2} < 0$ and $\frac{\partial^2 R_{22}}{\partial (p_{22})^2} < 0$, the revenue functions given quality levels are strictly concave in prices. The prices of both firms increase with their own quality level, i.e., $\frac{\partial p_{12}^{*}}{\partial k_1} > 0$ and $\frac{\partial p_{22}^{*}}{\partial k_2} > 0$, whereas the prices of both firms decrease with the quality level of its competitor, i.e., $\frac{\partial p_{12}^{*}}{\partial k_2} < 0$ and $\frac{\partial p_{22}^{*}}{\partial k_1} < 0$. The price of firm 1 increases, and the price of firm 2 decreases with an increase in switching costs, i.e., $\frac{\partial p_{12}^{*}}{\partial s} > 0$ and $\frac{\partial p_{22}^{*}}{\partial s} < 0$. This is a result of higher demand realized by firm 1 when switching cost is higher.

4.1.2 Quality Equilibrium

Firm 1 will set its quality level in period 1 by anticipating firm 2's optimal quality level. Given the equilibrium price functions at (2) and (3), the profit for firm 2 in the second period can be written as:

$$\Pi_{22} = N \frac{(s - 3t + \theta_1 k_1 - \theta_2 k_2)^2}{18t} - \delta \frac{k_2^2}{2} \tag{4}$$

Firm 2 determines k_2 as a function of k_1 by maximizing $\Pi_{22}(k_1, k_2)$. Consequently, k_2^{*} is derived as:

$$k_2^{*} = \frac{N(3t - s - \theta_1 k_1)\theta_2}{9t\delta - N\theta_2^2} \tag{5}$$

k_2^{*} is decreasing in firm 1's quality level, i.e., $\frac{\partial k_2}{\partial k_1} < 0$. Similarly, k_2^{*} is decreasing in *s*, i.e., $\frac{\partial k_2}{\partial s} < 0$.

4.2 Price Decisions

In this section, we solve for the quality level set by firm 1 as well the price it charges in period 1.

4.2.1 Period 1 Price Equilibrium

The location of the marginal customer x_0 (Figure 1) in period 1 can be obtained by equating the utility of the indifferent customer to zero because the choices of the consumers in this period buy firm 1's product or buy nothing.

$$x_0 = \frac{\theta_1 k_1 - p_{11}}{t} \tag{6}$$

Firm 1 maximizes its revenue in period 1 when it sets p_{11}. Its revenue in period 1 is given by:

$$\Pi_{11} = N\, x_0\, p_{11} \tag{7}$$

Maximizing the revenue function (7), we obtain p_{11}^*:

$$p_{11}^* = \frac{\theta_1 k_1}{2} \tag{8}$$

Since $\frac{\partial^2 \Pi_{11}}{\partial (p_{11}^*)^2} < 0$, the profit function given quality level is strictly concave in price.

4.2.2 Quality Equilibrium

In setting k_1 in period 1, firm 1maximizes its total future discounted profit given by $\Pi_1^{total}(k_1) = R_{11}(k_1) + r\, R_{12}(k_1) - \frac{k_1^2}{2}$, where $r < 1$ is the discount factor for the second period revenue.

The equilibrium quality levels k_1^* and k_2^* are derived as:

$$k_1^* = \frac{6t^2 Nr\delta\theta_1\ (3(3t+s)\delta - 2N\theta_2^2)}{2t(-9t\delta + N\theta_2^2)^2 - N\theta_1^2(9t^2(9+2r)\delta^2 - 18tN\delta\theta_2^2 + N^2\theta_2^4)} \tag{9}$$

$$k_2^* = \frac{N\theta_2[2t(3t-s)(9t\delta - N\theta_2^2) - N\theta_1^2(3t(t(9+4r)-3s)\delta - N(3t-s)\theta_2^2)]}{2t(-9t\delta + N\theta_2^2)^2 - N\theta_1^2(9t^2(9+2r)\delta^2 - 18tN\delta\theta_2^2 + N^2\theta_2^4)} \tag{10}$$

5 ANALYSIS OF THE EQUILIBRIA

We study the impact of s and δ through a comparative static analysis. We provide results without proofs in this section for brevity. The proofs involve straightforward but tedious algebraic manipulations and are available from the authors. Many of our results depend on the value of switching cost, more specifically whether the switching cost is low or high. These various cut-off values for switching cost, i.e., s_1, s_2, s_3, s_4, and s_5, separate the low from high switching cost regions. They are derived through the first order conditions of the equilibrium points over δ. We summarize those switching cost values used in our results in the following table.

s_1	$\frac{N\theta_2^2}{3\delta} - \frac{6t^2\delta r\theta_1^2 N}{(2t - N\theta_1^2)(9t\delta - N\theta_2^2)}$
s_2	$\frac{t[9c^2\delta^2(18t - N(9+2r)\theta_1^2)(18t - N(9+4r)\theta_1^2) - 18tN\delta(2t - N\theta_1^2)(18t - N(9+2r)\theta_1^2)\theta_2^2 + N^2(2t - N\theta_1^2)(18t + N(4r-9)\theta_1^2)\theta_2^4]}{3(2t - N\theta_1^2)\{2t(-9t\delta + N\theta_2^2)^2 + N\theta_1^2[-9t^2(9+2r)\delta^2 + 2tN(9+2r)\delta\theta_2^2 - N^2\theta_2^4]\}}$

s_3	$\dfrac{3\{2t(-9t\delta+N\theta_2^2)^2+N\theta_1^2[-27t^2(3+2r)\delta^2+2tN(9+4r)\delta\theta_2^2-N^2\theta_2^4]\}}{\{2t(-9t\delta+N\theta_2^2)^2+N\theta_1^2[9t^2(-9+2r)\delta^2+18tN\delta\theta_2^2-N^2\theta_2^4]\}}$
s_4	$t\left(3-\dfrac{4tNr\delta\theta_1^2}{(2t-N\theta_1^2)(9t\delta-N\theta_2^2)}+\dfrac{32tNr\delta\theta_1^2(-9t\delta+N\theta_2^2)}{2t(-9t\delta+N\theta_2^2)^2+N\theta_1^2(27t^2(-3+2r)\delta^2+18tN\delta\theta_2^2-N^2\theta_2^4)}\right)$
s_5	$t\left(3-\dfrac{8tNr\delta\theta_1^2}{(2t-N\theta_1^2)(9t\delta-N\theta_2^2)}+\dfrac{16tNr\delta\theta_1^2(-9t\delta+N\theta_2^2)}{2t(-9t\delta+N\theta_2^2)^2+N\theta_1^2(27t^2(-3+2r)\delta^2+18tN\delta\theta_2^2-N^2\theta_2^4)}\right)$

Proposition 1: *For a given δ, the quality, price, and profit of firm 1 increase whereas the quality, price, and profit of firm 2 decrease with an increase in switching cost.*

$$i.e.\ \frac{\partial k_1}{\partial s}>0,\quad \frac{\partial p_{12}}{\partial s}>0,\quad \frac{\partial \Pi_1^{total}}{\partial s}>0 \ \ and\ \ \frac{\partial k_2}{\partial s}<0,\quad \frac{\partial p_{22}}{\partial s}<0,\quad \frac{\partial \Pi_{22}}{\partial s}<0$$

Proposition 1 shows that higher switching cost benefits firm 1 and hurts firm 2, *ceteris paribus*. In order to attract the customers from firm 1, firm 2 has to charge a low price when consumers face switching costs. The lower price reduces firm 2's revenue. Lower revenue causes firm 2 to decrease its quality. The lower quality level and lower price reduce firm 2's profit when switching cost increases. However, firm 1 exploits its power over its customers when they face switching costs. The customers are locked-in more to firm 1 as switching cost increases leading firm 1 to increase its price. Consequently, firm 1 has an incentive to provide high quality in order to attract more customers in the first period and retain more of them in the second period. Thus, as the switching cost increases, firm 1's profit increases.

The result that a higher switching cost benefits the first-mover and hurts the second mover is consistent with our expectation. We also expect that a declining technology cost has an opposite effect on firms. Our next result relates to this impact.

Proposition 2: *The impact of δ on quality and price is summarized in the following table.*

$\frac{\partial}{\partial\delta}(\ )$	$s< s_1$	$s_1 < s < s_3$	$s_3 < s < s_2$	$s_2 < s$
k_1	+	-	-	-
k_2	-	-	-	+
p_{12}	+	+	-	-
p_{22}	-	-	+	+

The result shows that the effects of declining technology cost on firms depend critically on the value of the switching cost. One expects that a higher decline in technology cost will always favor the second mover, causing it to offer a higher quality and hurt the first mover causing it to offer a lower quality. We indeed find that when the switching cost is low, i.e., $s < s_1$, firm 1 offers a higher quality. Firm 1's second period demand will decrease with the competition as consumers have little incentive to stay with firm 1 when switching cost is low. Hence, anticipating the future competition from firm 2, which can get a higher quality at a lower cost, firm 1 reduces its investments as the technology cost declines, i.e., $\frac{\partial k_1}{\partial \delta} > 0$, to minimize its loss when consumers incur a low switching cost. A low switching cost, therefore, does not offset the cost disadvantage.

Our expectation related to the effect of a decline in technology cost on firm 2 is correct only when the switching cost is low, i.e., $s_2 < s$. The same reason as that given for firm 1 applies for firm 2 also. An interesting observation is that when $s_1 < s < s_2$, , both firms increase their quality when technology cost declines. That is, the behaviors with respect to quality of the two competing firms are not opposites of each other. This result can be explained as follows. At moderate levels of switching cost, switching cost offsets the cost disadvantage for firm 1, and cost advantage because of a decline in technology cost offsets the switching cost disadvantage for firm 2.

The behaviors of firms with respect to prices are similar to those of qualities, except that the cut off value for low and high switching costs are different.

We showed in proposition 2 that a moderate or high switching cost will offset the cost disadvantage and allows firm 1 to increase its quality and compete with firm 2 on quality. However, as shown in the next proposition, firm 1's is still hurt by declining technology cost. On the other hand, firm 2 may or may not benefit from a decline in technology cost. The effects of a declining technology cost on profits are summarized in the following result.

Proposition_3:

(i) Given switching costs, firm 1's profit decreases with declining technology cost, i.e. $\frac{\partial \Pi_1^{total}}{\partial \delta} > 0$

(ii) If $s < s_4$, then firm 2's profit increases with declining technology cost, i.e. $\frac{\partial \Pi_{22}}{\partial \delta} < 0$. *Otherwise*, $\frac{\partial \Pi_{22}}{\partial \delta} > 0$.

The above result shows that the switching cost does not change the negative impact of a declining technology cost on firm 1. In a low switching cost market, in the second period, firm 1 loses most of its first period customers to firm 2 as its competitor offers a higher quality product and the switching cost is not high enough to prevent its customers from switching. The low second period demand decreases firm 1's total profit. In a high switching cost market, firm 1 is able to retain most of its customers in the second period and offer high quality products with high prices. However, it also invests heavily to offer a high quality as technology cost declines, i.e., $\frac{\partial k_1}{\partial \delta} < 0$ (recall Proposition 2), which reduces its total profit.

The effect of a decline in technology cost on firm 2's profit depends on the value of the switching cost (Figures 4 and 5). When switching cost is high, firm 2 cannot enjoy the advantage of low investment cost. Firm 1 is able to retain most of its customers. Anticipating a low demand for its product, firm 2 decreases its investment, i.e., $\frac{\partial k_2}{\partial \delta} > 0$, to minimize its loss. Hence, the profit of firm 2 decreases. In this case being the second mover hurts firm 2 more than the declining cost benefits. Firm 2 is able to enjoy the benefit of a decline in technology cost only when switching cost is low.

We can now investigate the combined effect of switching cost and technology cost decline on firms' investment decisions.

Proposition_4:

(i) $\frac{\partial^2 k_1}{\partial \delta \partial s} < 0, \quad \frac{\partial^2 p_{12}}{\partial \delta \partial s} < 0$

(ii) $\frac{\partial^2 k_2}{\partial \delta \partial s} > 0, \quad \frac{\partial^2 p_{22}}{\partial \delta \partial s} > 0$

(iii) *If* $s < s_1$, *then* $\frac{\partial^2 \Pi_1^{total}}{\partial \delta \partial s} > 0$. *Otherwise*, $\frac{\partial^2 \Pi_1^{total}}{\partial \delta \partial s} < 0$

(iv) *If* $s < s_5$, *then* $\frac{\partial^2 \Pi_{22}}{\partial \delta \partial s} > 0$. *Otherwise*, $\frac{\partial^2 \Pi_{22}}{\partial \delta \partial s} < 0$.

The above proposition clearly illustrates the mediating effect of switching cost on the impact of declining technology cost. We can note from (i) a higher switching cost either increases or reduces the decline in k_1 when δ decreases. In other words firm 1 increases its investment when consumers face high switching costs. Exactly the opposite effect occurs for firm 2. The same results hold true for the pricing strategies of both firms.

Of additional interest, we have studied the effect of switching cost along with declining technology cost on profits. Proposition 3 showed that any positive switching cost is better than no switching cost for firm 1. Proposition 4 shows that when the switching cost is low, i.e., $s < s_1$, the decline in profit for firm 1 because of a decline in technology cost is higher at higher levels of switching cost. That is, in the region $s < s_1$, higher switching cost amplifies the negative effect on firm 1. When $s > s_1$, higher switching cost attenuates the negative effect. This result shows that the effect of switching cost dominates the effect of declining technology cost when switching cost is high. The opposite effect occurs for firm 2.

We illustrate our theoretical analysis with numerical examples for two sets of markets where $N = 100$, $t = 101$, $r = 0.92$, $\theta_1 = 1$, and $\theta_2 = 2$. In the first set (a), low switching cost market, the value of s is equal to 10 and in the second set (b), high switching cost market, the value of s is equal to 50. In both examples, we increase the value of s to 20 and then 60, respectively, to examine the effect of an increase in switching costs on the strategic behavior of firms. Figures 2 through 5 the numerical results for the valid ranges of δ for these examples. We can label the first set of examples where the switching costs are set at 10 and 20 as low switching cost market and the other half where the switching costs are set at 50 and 60 as high switching cost market. The qualitative nature of the numerical results validates our theoretical results. Of particular interest is the magnitude of quality, and profit figures for the firms. Quality and profit of firm 1 are significantly higher in the high switching cost market than in the low switching cost market. These figures provide an idea of the advantages firm 1 enjoys when there is a switching cost. Similar figures for firm 2 provide an idea about the extent of disadvantage faced by firm 2 because of a switching cost. On the other hand, we also note the extent of (dis)advantage declining technology cost offers firm 2 (firm 1). The profit of firm 1 quickly goes to zero. In our examples, firm 1 realizes a zero profit when firm 2's cost is 12 percent less than that of firm 1.

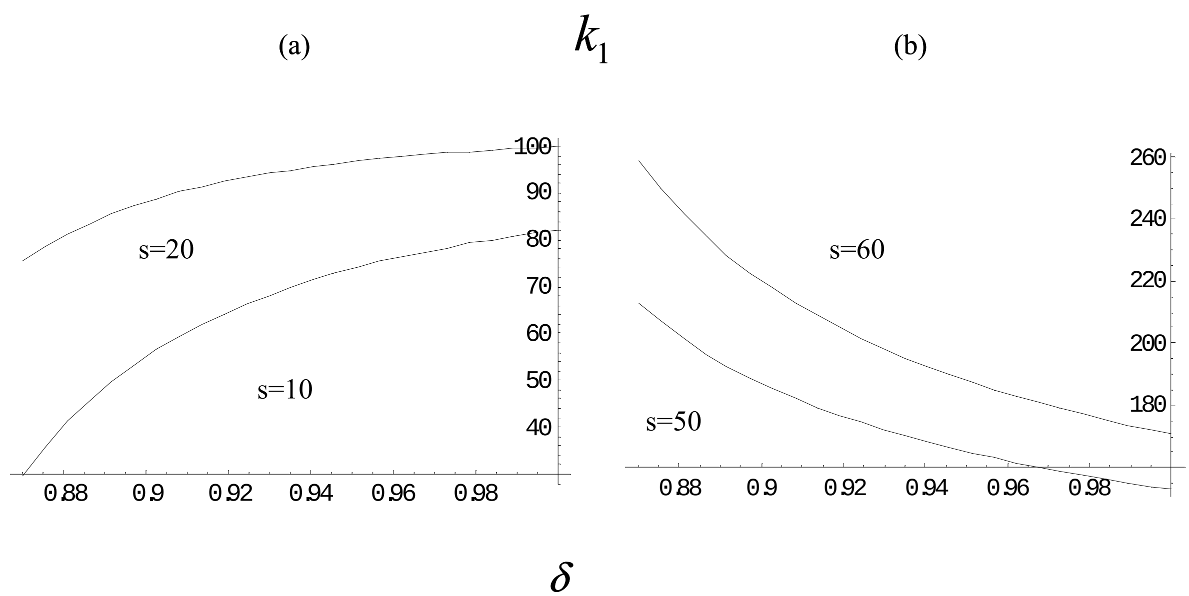

Figure 2. Quality of Firm 1

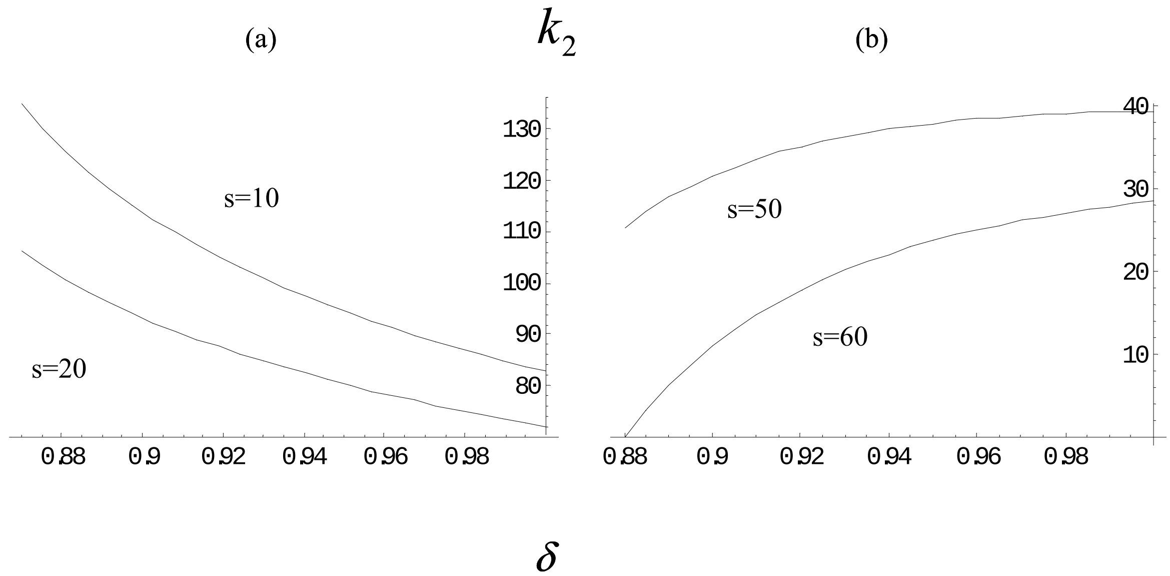

Figure 3. Quality of Firm 2

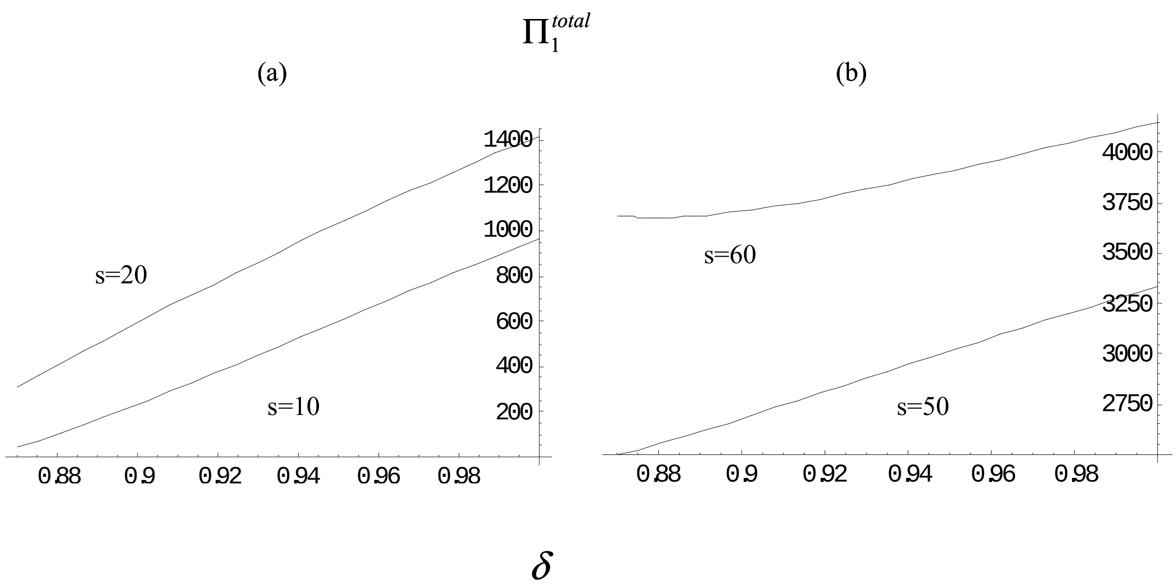

Figure 4. Profit of Firm 1

6 MANAGERIAL IMPLICATIONS AND CONCLUSIONS

We examined the problem of strategic IT investments in IT-intensive industries characterized by technology cost decline over time and consumer switching costs. We developed an economic model that focused on the cost difference between the two firms in the presence of consumer switching costs. The results of our study have significant implications for firms in the IT-intensive industries that face challenges because of rapid technological advances. Our analysis shows that an early entrant into the market may reduce the negative effect of a declining technology cost if it can impose switching costs on consumers. Hence, the first-movers might prefer to impose switching cost on consumers. In particular, Chen and Hitt (2000) showed that switching costs are significant in the online retail brokerage industry, and firms do appear to have significant influence over the switching costs their consumers incur.

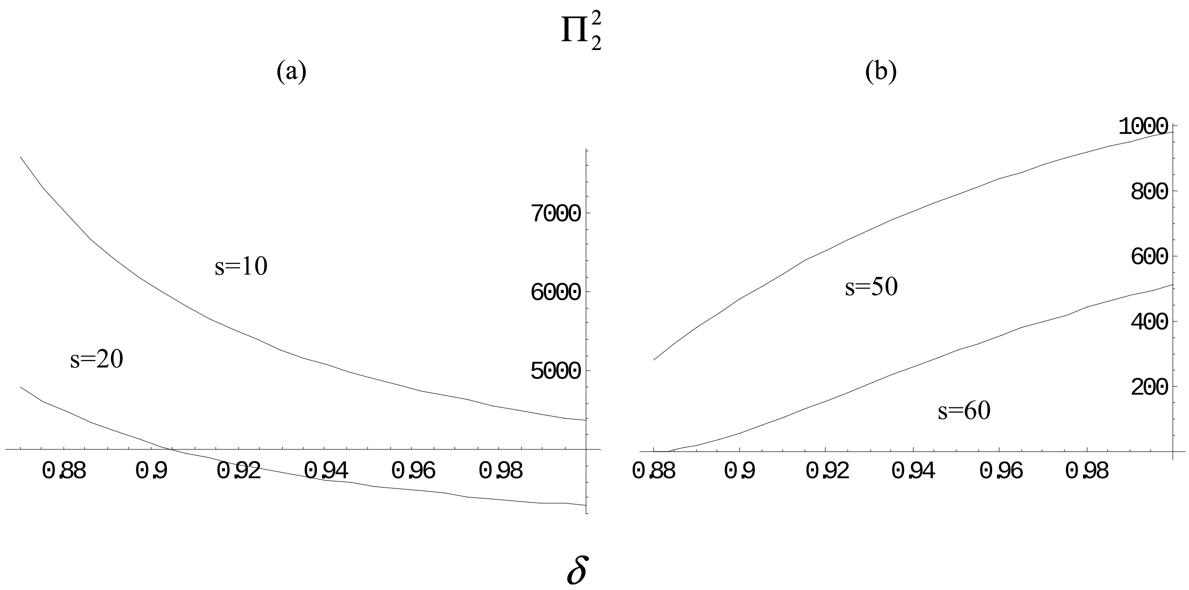

Figure 5. Profit of Firm 2

Let us turn to our ISPs example. What should ISPs do to protect themselves from a future competitor that may enjoy a lower cost of technology? Our results suggest two possible strategies. The first one is to design products and services that impose a higher switching cost on consumers. For instance, the basic Internet connection can be bundled with other value-added services. Instant messaging, e-mail, and Web hosting are some examples of these value-added services. Through these additional services, the firms impose switching costs on consumers. For example, services such as proprietary databases or search engines may make an existing consumer stay with the firm. Many ISPs are already repackaging their services along this dimension. For example, AOL, an early entrant in the market, has boasted about its security technology and key word search as value propositions to attract and retain customers. AOL's instant messaging service, which is incompatible with outside systems like those of Microsoft and Yahoo, also imposes switching costs to consumers already in its customer base (Lewis 2001).

A second strategy that the ISPs can use to impose switching costs is through long-term contracts. Such contracts are common for ISPs as well as the wireless phone service industry where technological advances are very rapid. With long-term contracts, the subscribers are locked in to pay the same price in each period during the contract term. If they switch to another firm and break the contract before it ends, they can be required to pay a penalty to the ISP. While we considered the case in which switching costs affect only the consumers directly, long-term contracts have the added benefit of transferring the switching costs as revenue to the firms. This pricing strategy may be especially effective if the consumer switching costs because of product characteristics are low. One of the limitations of long-term contracts is that they may reduce the number of consumers who buy in the first period. The question of which strategy is better for imposing switching costs, long-term contract versus product design, deserves further research.

The model has certain limitations. First, switching cost is assumed to be exogenous on our model. However, firms may be able to control switching costs and also derive additional revenue in this process. An example of such switching costs is long-term service contracts. Such contracts are common in ISPs as well as the wireless phone service industry where technological advances are very rapid. We are currently investigating these issues. Another critical assumption of the model is that there are only two firms operating in the market. We can relax this assumption in two different modeling ways: (1) the case where there are only two periods and in each period N firms enter the market, and (2) the case where N firms enter the market sequentially in N periods. We believe that the results of our two-firm model will carry over to the first case, although the expressions for quantities such as profit will change. Future research on extending our model to a more general problem of quality and price competition among N firms entering the market N sequentially (case 2) is likely to provide more general results. In both of these cases, the competitive intensity will increase as more firms are competing for a limited number of consumers. Thus, the competitive intensity as measured by the number of firms (Banker et al. 1998) would be an additional factor that may affect the equilibrium quality levels and profits. Furthermore, in an N period setting, as technology develops over time, an early entrant's cost disadvantage becomes more severe over time. Thus, it would be interesting to further study how the firms are affected by increasing competition and whether the firms that enter the market in the early periods can sustain their profitability despite the switching costs.

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