Managing Successive Generation Product Diffusion in the Presence of Strategic Consumers

Abstract

Frequent new product release and technological uncertainty about the release time pose significant challenges for firms to manage successive generation of products. On the one hand, strategic consumers may delay their purchase decision and substitute the earlier generation with the newer generation product. On the other hand, the firm must fully anticipate consumer reactions and take into account the effect of their strategic behavior on product pricing and successive generation product diffusion. This paper proposes a prediction market to forecast new product release. We show that the market information aggregation mechanism can improve forecast accuracy of new product launch. Better forecasting increases consumer surplus, firm revenue, and social welfare.

1. Introduction

Technology advances significantly speed up new product development, resulting in several generations of the same product coexist in the consumer market. The most familiar examples include Apple's iPod and iPhone family of products and Microsoft Windows and Offices lines of products. Newer models and versions are continuing to emerge. As the time interval between new product release decreases, it is important to understand the impact of new technologies on earlier ones.

The new generation technology gives consumers a better product that they value more. When new technologies become available, it provides an opportunity for potential adopters of earlier technologies to substitute the more recent technologies for earlier ones. In anticipation of price reductions, consumers may choose to wait for the sale. This is termed as inter-temporal substitution by customers, which diminishes the potential sales of the earlier technologies. Ignoring such strategic behaviors from consumers will lead to the firm's sub-optimal pricing decisions.

On the other hand, the adoption of new products follows a diffusion process in a social-technological system. Even if the substitution is under way, earlier technologies will continue to diffuse through the population. Both substitution and diffusion need to be understood when assessing and forecasting the influence of new technologies on earlier ones.

Clearly, understanding consumers' decisions about which product to buy and when to buy and how consumers behave in the technology market deserves careful attention. However, there are several challenges when managing successive generation product diffusion. First, due to the fear of possible cannibalization of sales for the first generation product, firms usually do not have incentive to disclose their new product release information. Because of such strategic concern, even if firms are willing to reveal such information, firms' signals may be perceived as incredible. Strategic communication of information such as cheap talk is impossible. In addition, there exists technological uncertainty about the release time, as it largely depends on project success in new product development. Therefore, the true probability of new product release at certain time is unknown.

To solve this information sharing dilemma, we propose a market system to predict the new product launch. Prediction markets are very useful for estimating the market's expectation of uncertain events. The best known prediction market is the Iowa Electronic Market. Various forms of prediction markets show the power of markets to provide information about probability of future events. A number of successes in these markets, both with regard to public events like presidential elections and within firms, have generated substantial interest in designing markets that leverage distributed knowledge of participants.

Today, the technology savvy consumers are well informed about the technology potential from many channels. They form expectations about price decrease, new product release, as well as new capabilities of the next generation product. We design a prediction market specifically for revealing and aggregating product release information. The final payoff structure of the trading contract provides incentive for truthful information revelation. Price fluctuation reflects ongoing development of news and information about the new product release.

Building upon basic insights from the seminal Bass product diffusion model (Bass 1969), Norton and Bass multi-generation model (Norton and Bass 1987), we describe diffusion dynamics across successive generation of products. Our model assumes that each generation has its own market potential and market penetration process. Potential adopters of earlier generations can shift to newer generations through substitution. In contrast to most existing literature that treats consumer demand as an exogenous arrival process. We model demand dependencies that arise due to substitution effects across the two generations of products. By fully anticipating strategic consumers' response, we examine how firms should design their selling mechanisms in order to maximize expected profits.

2. Model Assumptions and Strategic Consumers

We assume the firm sells two generations of the product. The first generation of the product is introduced at $t = 0$, and the second generation is introduced at $t = \tau > 0$. This model setup is motivated by Apple's iPhone release. Following the announcement of iPhone4 in June 2010, the 3GS is only available in an 8GB version and the iPhone 3G was officially discontinued. Therefore, a two-generation model in the product market is sufficient.

We assume the first generation product is priced at p before the second generation product is available; when the second generation product is introduced, the second generation is priced at p and the first generation is sold at a discounted price $-\Delta$. This pricing strategy is frequently observed in the high tech product market. For example, Apple's first generation iPad was introduced on April 3, 2010. Its entry model iPad with Wi-Fi 16GB model was priced at $499. When the second generation iPad2 is introduced, the new Wi-Fi 16GB model is sold at the same price as its first generation. The first generation model price dropped to $399.

2.1. Before the Introduction of the Second Generation Product (When $t < \tau$)

Because the second generation product availability depends on the new product debelopment project success, consumers face uncertainty about product availability. In the following, we analyze the consumer's wait-or-buy decision in terms of individual utilities.

We assume that a consumer derives heterogeneous utility $v \in [0,1]$ by consuming the first generation product, where v is a random variable drawn from a uniform distribution [0,1]. We further assume that the consumer enjoys a higher utility ρv, where $\rho > 1$, for the second generation product due to enhanced functionalities, better quality, and so on.

At time $t < \tau$, if a consumer chooses to wait for the second generation product, the consumer incurs a waiting cost $c(\tau - t)$, where c is the per unit waiting cost. Linear waiting cost has been extensively used in queuing theory, where c is interpreted as waiting-cost rate (per unit time waiting cost) and the waiting-cost function is linear in the expected waiting time. Mendelson and Whang (1990) used a similar linear delay cost function. Since we use linear waiting cost to model the decay of consumer utility, our parameter c models the degree of patience.

If a consumer decides to buy the first generation product at time t, the consumer obtains a net utility of $v - p$. If the consumer decides to wait for the second generation product, then depending on the true probability of project success, she can obtain the product with probability

θ. If she is able to buy the second generation product, she obtains net utility $\rho v - p - c(\tau - t)$; otherwise, she would buy the first generation product with a net utility $v - p - c(\tau - t)$. Therefore, a potential consumer at time t has expected utility $\theta[\rho v - p - c(\tau - t)] + (1-\theta)[v - p - c(\tau - t)]$. That is, $(\rho\theta - \theta + 1)v - p - c(\tau - t)$. Accordingly, we have the following result about consumers' wait-or-buy decision.

Lemma 1: *There exist thresholds* $\underline{t} = \tau - \frac{(\rho-1)\theta}{c}$, $\bar{t} = \tau - \frac{p(\rho-1)\theta}{c}$, *and* $\bar{v} = \frac{c(\tau-t)}{(\rho-1)\theta}$, *such that* $\underline{t} < \bar{t} < \tau$ *and*

a) all affordable consumers would purchase the first generation product if $t \leq \underline{t}$*;*

b) consumers whose utility $v < \bar{v}$ *would buy the first generation product and those utility* $v \geq \bar{v}$ *would wait for the second generation product;*

c) all affordable consumer would wait for the second generation product if $t \geq \bar{t}$.

Note that $\frac{\partial \bar{v}}{\partial t} = -\frac{c}{(\rho-1)\theta} < 0$. If a consumer with valuation v would prefer to wait for the second generation product at time t, then all consumers with valuation v and above also prefer to wait for the second generation product at time $t^{'} > t$.

Moreover, $\frac{\partial \bar{v}}{\partial \theta} = -\frac{c(\tau-t)}{(\rho-1)\theta^2} < 0$. It shows the connection between consumers' behavior and the probability of project success θ. The probability of new product development project success is similar to the concept of fill rate in the literature. The higher is the fill rate, the less risky is the stockout. Similarly, higher probability of project success will lower the threshold $\bar{v}$ and more consumers would like to wait for the second generation product.

We assume that, at any moment, the demand for the entire market is the total shopping intensity of individual consumers. Based on the definition of Levin et al. (2005), the shopping intensity is proportional to the probability that the valuation exceeds the current product price.

We are able to derive the following market segmentation.

Proposition 1: *Before the introduction of the second generation product, the proportion of strategic consumers who would buy the first generation product is:*

$$\begin{cases} 1-p & t \le \underline{t} \\ \frac{c(\tau-t)}{(\rho-1)\theta}-p & \underline{t} < t < \overline{t}; \\ 0 & t \ge \overline{t} \end{cases}$$

The proportion of strategic consumers who would wait for the second generation product is:

$$\begin{cases} 0 & t \le \underline{t} \\ 1-\frac{c(\tau-t)}{(\rho-1)\theta} & \underline{t} < t < \overline{t}. \\ 1-p & t \ge \overline{t} \end{cases}$$

2.2. After the Introduction of the Second Generation Product (When $t > \tau$)

If the second generation product is introduced, the newer generation product brings higher consumer surplus, i.e., $\rho v - p > v - p$. Consumers would prefer the newer model. With the price cut, consumers will choose the model that brings her higher surplus. The indifference consumer's utility can be calculated as: $\tilde{v} = \frac{\Delta}{\rho-1}$. Therefore, we have the following result.

Lemma 2: *When $t \ge \tau$, there is a threshold valuation $\tilde{v} = \frac{\Delta}{\rho-1}$ such that the strategic consumer whose valuation $v \ge \tilde{v}$ would prefer to buy the second generation product and whose valuation $v < \tilde{v}$ would still prefer to buy the first generation product at the discounted price.*

Proposition 2: *After the second generation product is introduced, $1-\frac{\Delta}{\rho-1}$ proportion of strategic consumers would substitute for the second generation product, $\frac{\rho\Delta}{\rho-1}-p$ proportion of strategic consumers would still prefer the first generation product.*

We see that the market segmentation is time invariant. As Δ increases, the proportion of strategic consumers who prefer the first generation product increases.

We see that, before the introduction of the second generation product, the total proportion of consumers who can afford the product when $t < \tau$ is $1 - p$. When $t \in (\underline{t}, \bar{t})$, the proportion of consumers who choose between immediate purchase of the first generation product and waiting for the second generation product is time dependent. As t increases, more consumers would like to wait for the second generation product.

After the introduction of the second generation product, the total proportion of consumers who can afford the product increases by Δ. So the total proportion of consumers who can afford the product when $t \geq \tau$ is $1 - p + \Delta$.

Figures 1 and 2 in the Appendix compare the market segmentation with and without the introduction of the second generation product. We see that, in the demand model, consumer purchase probability changes over time. Clearly the proportion of consumers who are interested in buying the first generation product is a stepwise linear decreasing function of time. As shown, strategic consumers' purchase strategy is a time dependent threshold policy.

3. Market Game and Information Disclosure

In May 2010, Wal-Mart dropped the price of iPhone 3GS with 16 gigabytes of storage space with a two-year contract with AT&T from \$197 to \$97. That's a sign Apple was getting ready to unveil a new model. However, Apple declined to comment on whether it's planning to release a new iPhone soon, or whether it will also sell the iPhone 3GS for less. Apparently, Apple does not have an incentive to share its product release information. In this section, we describe the market game and discuss incentives for information disclosure.

3.1. Market Game

In our market game, the seller acts as a Stackelberg leader announcing his contingent and fixed-discount pricing strategy. Consumers take the seller's strategy as given and determine their purchasing behavior. We identify a subgame-perfect Nash equilibrium and show that given the seller's strategy, the equilibrium in the consumer subgame is unique and consists of time dependent threshold purchasing policies.

We assume that no consumers possess perfect market information, but consumers observe signals about the likelihood of new product introduction. Let subscript g, b, m represent scenarios where a consumer receives a good signal, bad signal, and the aggregated market signal. We have the following result:

Proposition 3: *There exists a Bayesian Nash Equilibrium for the game under no information sharing, where strategic consumers would buy the first generation product when* $t < t_i$ *and wait for the second generation product when* $t > t_i$ *, where*

$$t_i = \tau - \frac{\theta_i v(\rho-1)+(1-\theta_i)\Delta}{c}, \text{ where } i = g, b, m.$$

When there is no information disclosure, individual consumers would purely rely on the time to make decision. At any time t, if the customer's utility from buying is strictly greater than her utility from waiting, the customer would buy the first generation product. Otherwise, the customer would wait.

The seller's equilibrium pricing strategy $p(\bar{v}(\theta, t))$ will depend on the state $\bar{v}(\theta, t)$, which in turn, is determined by θ and t. The Bayesian Nash Equilibrium requires that both the firm and the customers do not have any unilateral profitable deviation from the strategy profile which defines the equilibrium. Specifically, the first condition requires that, when fixing the strategy of the strategic consumers and the firm, the strategic consumer should not have any profitable deviation. The second condition requires that, given the strategic consumers' best response actions, the firm maximizes its profit by using the announced strategy. A Bayesian Nash Equilibrium is a babbling equilibrium if the customer's actions in equilibrium do not depend on the information provided by the firm. The following result shows that it is impossible for the firm to credibly communicate any information to customers.

Proposition 4: *The strategic consumers' purchase decision is independent of the firm's signal of project success.*

Therefore, the action of the strategic consumers taken in equilibrium is independent of what the firm announces, due to the lack of credibility of such an announcement. The overall purchasing probability is unaffected by the messages provided by the firm. In the following section, we discuss the information structure and propose a prediction market model to credibly predict the new product development project success.

3.2. Information Structure

We assume that, although the product firm may have better knowledge than consumers about the likelihood of project success, the true probability of new product release is $\theta > \frac{1}{2}$, which is an unknown parameter due to technology uncertainty. Many factors may affect the new product development success. Technology savvy consumers may obtain either good signals (denoted as $s = 1$) or bad signals (denoted as $s = 0$). For example, information that a key supplier has developed a new chip model can be viewed as a good signal, and recent failure of a related project by the same product firm is perceived as a bad signal. We assume $P(s = 1|\theta) = \phi > \frac{1}{2}$. That is, a consumer is more likely to receive a good (bad) signal since the firm's true success rate is greater than 1/2. Accordingly, $P(s = 0|\theta) = 1 - \phi$. In addition, we assume the prior belief about the firm's new product release is $\Pr(\theta) = \pi$.

Consumers who receive different individual signals would update their beliefs differently. The expressions are as follows:

$$P(\theta|s = 1) = \frac{\pi\phi}{\pi\phi + (1-\pi)(1-\phi)}; \; P(\theta|s = 0) = \frac{\pi(1-\phi)}{\pi(1-\phi) + (1-\pi)\phi}.$$

We propose a prediction market in which a binary contract is traded. The contract pays off \$1 if the second generation product is introduced at time τ, and it pays off \$0 if the second generation product is not introduced at time τ.

We assume the number of consumers who receive signals is proportional to the total cumulative sales of the first generation product. That is, as the time for new product release approaches, more signals about the new product development are available. Therefore, we assume consumers receive signals following a binomial distribution with parameters $(\delta x(t), \phi)$, where $\delta < 1$ representing the proportion of consumer population who care about or who are interested in collecting signals. $x(t)$ is the cumulative sales of the first generation product up to time t. So the expected number of consumers who have received $s = 1$ is $G(t) = \delta\phi x(t)$ and the total number of consumers who have received $s = 0$ is $B(t) = \delta(1-\phi)x(t)$. As a result, the market price for this binary contract is expressed in the following Proposition.

Proposition 5: *If consumers who receive independent signals trade in the prediction market, the market price at time t is the predicted probability of new product release:*

$$q^*(t) = f\big(\theta \big| G(t), B(t)\big) = \frac{\pi\phi^{G(t)}(1-\phi)^{B(t)}}{\pi\phi^{G(t)}(1-\phi)^{B(t)} + (1-\pi)(1-\phi)^{G(t)}\phi^{B(t)}};$$

Moreover, $\lim_{t\to\tau} |q^*(t) - \theta\,| < \varepsilon(\delta, x(\tau))$.

It shows that the proposed market mechanism can effectively collect and aggregate the signals dispersed among individual consumers. At any time, the market price can be interpreted as the probability of the new product release. When the time approaches the scheduled release time, the market predicted probability is very close to the true probability of project success. The predictive error is bounded by an error term ε, which depends on the consumer interest of collecting and trading signals as well as the total market penetration of the first generation product at time τ.

4. Two Generation Product Diffusion Model with Strategic Consumers

Let m_1 be the market potential for the first generation and m_2 be the potential uniquely served by the second generation. It can be considered as an incremental market for newer generation. $f(t)$ is the probability of adoption at time t. $F(t)$ is the fraction of the ultimate potential adopters by time t. It is the probability of purchase given that the consumer has not purchase the product by t.

Assume μ portion of the consumer population is non-strategic consumers who would purchase the first generation product without considering the possibility of the better, second generation product.

We assume linear demand function. At any time t, the total market demand is $D(t) = m_1(1 - p - \frac{x(t)}{m_1})$. Here $1 - p$ is the proportion of affordable consumers, $\frac{x(t)}{m_1}$ is the proportion of population that has already adopted the product, and the term in the bracket is the probability of purchase from remaining consumers. Assume $x(0) = 0$, the initial market potential is $D(0) = m_1(1 - p)$. This is the maximum market size for the first generation product if it is priced at p.

Under decentralized information scenario, consumers individually observe private signals. If the second generation product is indeed introduced, the instantaneous sales for the first generation product can be expressed as:

$$\dot{x}^d(t) = \begin{cases} m_1(\alpha_1 + \beta_1 \frac{x(t)}{m_1})(1 - p - \frac{x(t)}{m_1}) & t < t_g \\ m_1\left(\alpha_1 + \beta_1 \frac{x(t)}{m_1}\right)[(1-\mu)\left(\frac{c(\tau - t)}{(\rho - 1)\theta} - p\right) + \mu(1-p) - \frac{x(t)}{m_1}] & t_g \le t < t_b \\ m_1(\alpha_1 + \beta_1 \frac{x(t)}{m_1})[\mu(1-p) - \frac{x(t)}{m_1}] \quad t_b \le t < \tau \\ m_1\left(\alpha_1 + \beta_1 \frac{x(t)}{m_1}\right)[\frac{\rho\Delta}{\rho - 1} - p - \frac{x(t)}{m_1}] \quad t \ge \tau \end{cases}$$

Note that the first three equations of the demand dynamics are based on Proposition 1 and the fourth equation is based on Proposition 2. Otherwise,

$$\dot{x}^n(t) = \begin{cases} m_1(\alpha_1 + \beta_1 \frac{x(t)}{m_1})(1 - p - \frac{x(t)}{m_1}) & t < t_g \\ m_1 \left(\alpha_1 + \beta_1 \frac{x(t)}{m_1}\right) [(1-\mu)\left(\frac{c(\tau - t)}{(\rho - 1)\theta} - p\right) + \mu(1-p) - \frac{x(t)}{m_1}] & t_g \le t < t_b \\ m_1(\alpha_1 + \beta_1 \frac{x(t)}{m_1})[\mu(1-p) - \frac{x(t)}{m_1}] \quad t_b \le t < \tau \\ m_1(\alpha_1 + \beta_1 \frac{x(t)}{m_1})(1 - p - \frac{x(t)}{m_1}) \quad t \ge \tau \end{cases}.$$

Based on insights from the multi-generation model of Norton and Bass (1987), the instantaneous sales for the second generation product when $t > \tau$ can be expressed as:

$$\dot{y}^d(t) = m_2(\alpha_2 + \beta_2 \frac{y(t-\tau)}{m_2}) \left(1 - p - \frac{y(t-\tau)}{m_2}\right) + m_1(\alpha_1 + \beta_1 \frac{x(t)}{m_1}) \left(1 - \frac{\Delta}{\rho - 1} - \frac{x(t)}{m_1}\right).$$

At $t = \tau$, we have:

$$y^d(\tau) = (1-\mu) \int_{t_g}^{t_b} \left(1 - \frac{c(\tau - t)}{(\rho - 1)\theta}\right) m_1(\alpha_1 + \beta_1 \frac{x(t)}{m_1}) dt + (1-\mu) \int_{t_b}^{\tau} (1-p)\, m_1(\alpha_1 + \beta_1 \frac{x(t)}{m_1}) dt$$

This is the demand that from strategic consumers who have decided to wait for the second generation product rather than purchasing the first generation product. This is the substitution effect.

With the prediction market, the cumulative sales for the first generation product can be expressed as:

$$\dot{x}_s^m(t) = \begin{cases} m_1(\alpha_1 + \beta_1 \frac{x(t)}{m_1})(1 - p - \frac{x(t)}{m_1}) & t < t_m \\ m_1 \left(\alpha_1 + \beta_1 \frac{x(t)}{m_1}\right) [\mu(1-p) - \frac{x(t)}{m_1}] & t_m \le t < \tau. \\ m_1 \left(\alpha_1 + \beta_1 \frac{x(t)}{m_1}\right) \left[\frac{\rho\Delta}{\rho - 1} - p - \frac{x(t)}{m_1}\right] [1 - p - \frac{y(t-\tau)}{m_1}] & t \ge \tau \end{cases}$$

$$\dot{y}^m(t) = \left(1 - p - \frac{y(t-\tau)}{m_2}\right) m_2(\alpha_2 + \beta_2 \frac{y(t-\tau)}{m_2}) + m_1(\alpha_1 + \beta_1 \frac{x(t)}{m_1}) \left(1 - \frac{\Delta}{\rho - 1} - \frac{x(t)}{m_1}\right).$$

At $t = \tau$, we have $y^d(\tau) = (1-\mu) \int_{t_m}^{\tau} (1-p)\, m_1(\alpha_1 + \beta_1 \frac{x(t)}{m_1}) dt$.

With the prediction market, when $t_g \le t < t_m$, some optimistic consumers who receive good signals will adjust their belief so that they will not delay their purchase to the second generation. This helps the seller to realize sales early rather than late. When $t_m \le t < t_b$, some pessimistic consumers who receive bad signals will adjust their belief so that they can wait for the second generation of the product. This helps increase the consumer surplus because consumers value the second generation product more than the first generation product. As long as consumers can afford the waiting cost, those consumers would better off if they wait and the second generation product is indeed introduced.

5. Numerical Illustration

In his section, we use a numerical example to show the impact of strategic consumer behavior on pricing policies and expected revenue. Assume that the firm uses a markdown pricing mechanism. At the beginning, the firm announces the schedule of prices (p, Δ). The first generation product is priced at p. If the second generation product is successfully introduced at τ, the second generation product is priced at p and the first generation product is sold at discounted price $p - \Delta$. If the second generation product is failed to market, the first generation product is still priced at p. In the numerical example, we take m_1=1000, m_2=500, $= 0.8$, T=10, τ =5.

Recall that μ represents the portion of non-strategic consumers in the population. When $\mu = 0$, all consumers are strategic and they may practice inter-temporal substitution. When $\mu = 1$, all consumers are myopic and they would make a one-time purchase decision at the time of arrival. Figure 3 in the Appendix shows the sub-optimality gap on the portion of strategic consumers under different information structure. When all consumers in the population are non-strategic, the information structure does not matter for the seller's revenue. Under the decentralized information structure, even if the seller takes into account strategic consumers' behavior, the revenue is only 62% of that without strategic consumers. The presence of strategic consumers reduces the seller's revenue. Moreover, if the seller incorrectly assumes that strategic consumers are myopic in their purchasing decisions, it can be quite costly, leading to 32%

decrease of potential revenue under decentralized information sharing. However, market-based information aggregation can improve the firm's performance.

Recall that when the per unit waiting cost *c* is high, consumers are less patient. Figure 4 shows the optimal pricing under different degree of patience of strategic consumers. We see that, with strategic consumers, the firm needs to set a lower selling price for the product. Intuitively, this will discourage strategic consumers from waiting. The selling price is lower when the strategic consumers are less patient. This gives impatient consumers incentives to buy early. As a result, when the second generation product is available, the seller is able to heavily discount the first generation because the channel cannibalization effect is not too severe, and major purpose of discounting is to pick the remaining market potential.

In contrast, when strategic consumers are relatively patient, the seller would prefer a relatively high selling price for the product and set a smaller discount for the first generation product when the second generation is available. This is primarily because the seller cannot effectively induce strategic consumers to purchase the product early. The lower price discount when the second generation is available is a strategy to prevent channel cannibalization.

6. Conclusion

This paper shows the importance of taking into account strategic consumers' purchase behavior when managing successive generation product diffusion. Because firms cannot credibly share product information with consumers, we propose a prediction market to achieve effective information aggregation. Our numerical example demonstrates that more effective information sharing can improve firm performance. Moreover, we find that if firms fail to account for strategic consumer behavior and overlook the demand dependency due to product substitution, the loss of revenue can be substantial. Optimal pricing decision should trade off such demand dependency between the two generations of products. Our numerical study suggests the first should take a different pricing strategy in the presence of strategic consumers.

There are a couple of limitations for this study. First, we do not consider capacity rationing. That is, the firm does not manipulate product availability to influence consumers' timing of purchase. Second, although we consider consumer learning effects, we do not incorporate valuation uncertainty in our model. Finally, although our focus in this study is to understand the diffusion dynamics across generations, future work may examine optimal market entry timing for product line extensions or new product generations.

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Appendix

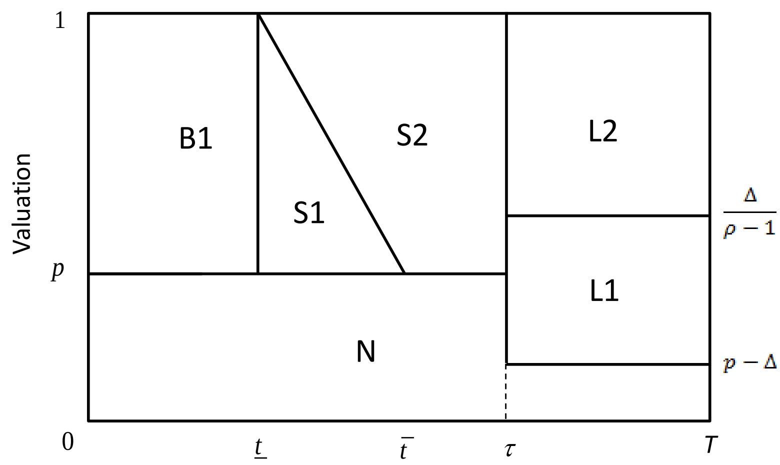

Figure 1: Market Segmentation if Second Generation Product Introduction is Successful

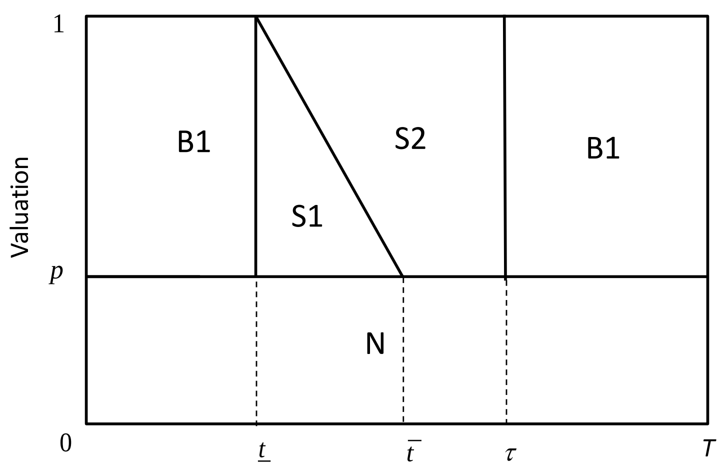

Figure 2: Market Segmentation if Second Generation Product Introduction is Unsuccessful

B1: immediate buy the first generation product

S1: strategic wait and desire to buy the first generation product at discounted price (market expansion)

S2: strategic wait and desire to buy the second generation product (substitution)

L1: immediate purchase the first generation product at discounted price (market expansion)

L2: immediate purchase the second generation product (substitution)

N: unaffordable for both generations of products

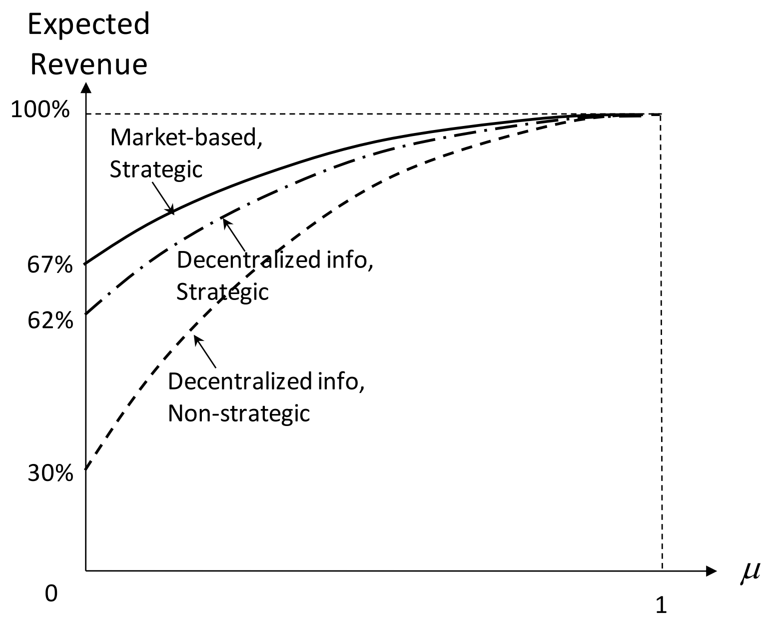

Figure 3: Sub-Optimality Gap under Different Information Structure and the Seller's Consideration of Strategic Consumer

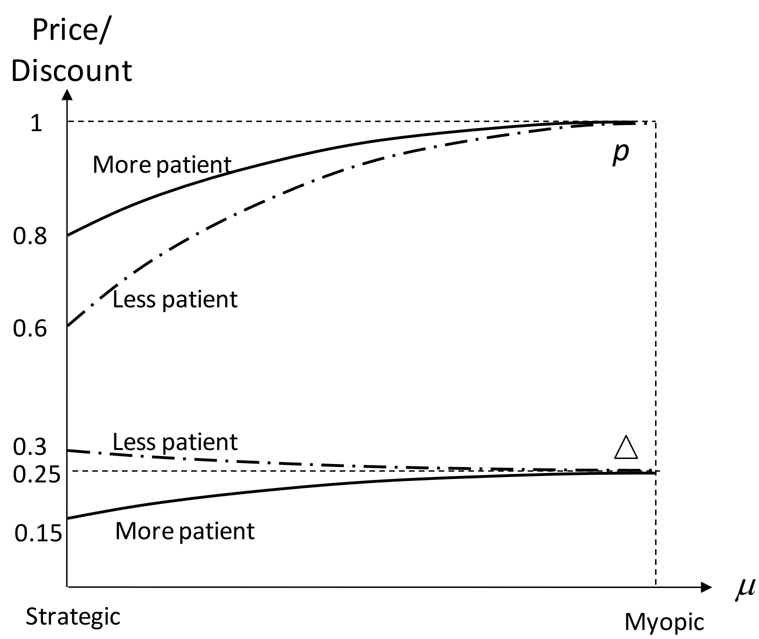

Figure 4: Price and Discount when Strategic Consumers are More or Less Patient under Market-Based Information Aggregation