

**NEW PRODUCTS, UPGRADES, AND NEW
RELEASES: A RATIONALE FOR
SEQUENTIAL PRODUCT INTRODUCTION**

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97/06/MKT

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Printed at INSEAD, Fontainebleau, France.

**NEW PRODUCTS, UPGRADES, AND NEW RELEASES:
A RATIONALE FOR SEQUENTIAL PRODUCT INTRODUCTION**

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October 1995
First Revision: January 1996
Second Revision: May 1996
Third Revision: January 1997

We thank Professors Rajiv Lal, Ivan Png, Ram Rao, V. Srinivasan, Garth Saloner, Seungjin Whang and seminar participants at Stanford University, University of California at Berkeley, University of Chicago, University of Texas at Dallas, University of Toronto and Washington University for their valuable suggestions. We also gratefully acknowledge the helpful comments and suggestions of the Editor, Professor Vijay Mahajan, and four anonymous reviewers. The usual disclaimer applies.

ABSTRACT

Network externality is an important consideration in many high-technology product markets. In these markets, consumers' expectations about the future installed base and the resultant externality benefits play a critical role in their product adoption decisions. We investigate the strategic implications of consumer uncertainty regarding network externality and analyze how a firm, endowed with high externality, can create favorable consumer beliefs about the anticipated installed base of its product, through its new product introduction strategy.

We first consider a market where consumers are homogeneous in their valuation of quality and show that under complete information, the optimal strategy entails introducing full (efficient) quality in the first period itself; providing any upgrade in the second period is sub-optimal. However, under asymmetric information about externality, a high-externality firm provides less-than-full quality initially and then makes the quality differential through provision of an upgrade in the second period. Thus, under-provision of introductory quality (i.e., withholding quality) serves as a signal of high externality. We demonstrate the robustness of this insight even in the presence of consumer heterogeneity on quality-valuation. We further show that externality signaling in heterogeneous market entails sequential targeting of consumer segments thereby providing a rationale for the phenomena of new products, upgrades and new releases.

KEY WORDS: Network Externality; New Product Introduction; Asymmetric Information; Adverse Selection; Signaling; Game Theory.

1. INTRODUCTION

Network externality or demand externality effects are important in diverse product markets such as telephones, facsimiles, software and voice mail. The benefit to a consumer increases with the number of users of the product when network externalities are present. These benefits arise due to a number of reasons. For instance, there is a benefit from the ability to share or exchange information in a standardized format with a larger number of users. Ancillary products are also more likely to be developed by outside firms when externality effects are important. Celebrated examples of product success due to network externality benefits are Microsoft's MS-DOS operating system and QWERTY key board (see Saloner and Shepard, 1995, for additional evidence).

The presence of network externalities implies that consumers' adoption decision and their willingness to pay for the product increases with the demand associated with a product. However, when a firm introduces a new product, the magnitude of potential demand associated with the product is private information. In other words, while the firm can through pre-launch market research ascertain the market potential (and hence the demand externality) associated with its product, consumers do not have access to this information and are therefore wary of believing the firm's claims about the product's demand potential. The following examples illustrate this phenomenon in the technology market. The most optimistic market forecast by industry watchers in the late seventies of the size of the personal computer market in 1985 was \$2 billion. The actual size of the market in 1985 exceeded \$25 billion and was closer to the estimate of industry entrepreneurs such as Steve Jobs, Ben Rosen and Rod Canion (McKenna, 1988). Similarly, there were few believers of Intuit CEO Scott Cook's estimate that the potential market for off-line home finance software in 1985 in California alone was close to 250,000.¹ Currently, Intuit is the leading player in the personal finance software market with a market of about 7 million (*San Francisco Chronicle*, May 25, 1995). The interested reader is referred to Cringely (1992), Ferguson and Morris (1993) and McKenna (1989) for more examples of this phenomenon in the technology market.²

The preceding examples illustrate discrepancies between firm's estimate of market potential and consumers'/industry-watchers' opinion of the same. There are several instances in the literature where a new product (with a superior product design and features) failed primarily because of unfavorable consumer expectations. Celebrated examples include the success of Remington' QWERTY typewriter keyboard (David, 1985) and failure of Sony's Betamax (Cusumano, Mylonadis, and Rosenbloom, 1992). Currently,

1. To put this in the right historical context, Cook was making this prediction at a time when the home banking ventures of Bank of America, Citibank, Chase, etc., were struggling to generate a total of 50,000 consumers (*Forbes*, November 11, 1984; *American Banker*, October 23, 1984). It is significant to note that the primary driver of Cook's estimate was the extensive market research conducted by Intuit. In fact, Cook spent six months doing market research before hiring his first programmer.

2. Firms may be positively biased in estimating the demand for the product. Under this condition, experts' estimate may more accurately reflect the true market potential.

industry experts believe that consumer expectations will determine the success or failure of products in the operating systems and High Definition TV market.³

The impact of favorable consumer expectations on the success of a new product launch underscores the need for managers to understand how a firm can, through its marketing strategy, credibly communicate information about the demand potential for its product. The word 'credible' is significant because consumers realize that any firm, irrespective of the true demand potential, will claim a high externality benefit for its product. Given the significance of network externality effects in technology markets, we believe that creating favorable consumer beliefs about the installed base for a new product is extremely important strategic consideration for managers. We show that a sequential product introduction strategy featuring new product introduction followed by upgrades and new releases can credibly communicate private information about network externality to the consumers.

Clearly, the subject of new products and upgrades is complex and rich in institutional and technical details. No single theory can comprehensively model all of the pertinent issues in this area. Our model is an abstraction and our theory suggests that information asymmetry may be one reason for upgrades and new releases. We offer a number of examples in the paper that are not inconsistent with the model assumptions and predictions. Justifiably, such evidence is best labeled as anecdotal or casual and should be interpreted within that context. Complementary models and approaches will be necessary to broaden our understanding of this important subject.

1.1 Background Literature

The subject of network externality has been the focus of considerable research in recent years. Farrell and Saloner (1985; 1986) and Katz and Shapiro (1985; 1986) analyze the demand- and supply-side implications of network externality. However, the extant literature has not explored the possibility of consumer uncertainty about network externality and analyzed its strategic implications. Moorthy and Png (1992) analyze the optimal launch strategy of a seller in a heterogeneous consumer market. They suggest that a sequential product introduction strategy wherein the firm initially serves only the high-valuation segment and later launches lower-quality versions to serve the low-valuation segments may be optimal when the consumers and the seller have different time preferences (discount rates). However, their model does not incorporate externality effects and they do not consider information asymmetry. Further, the optimal sequential launch in their model does not entail provision of any upgrades to the high-valuation consumers.

In the context of sequential bargaining, Vincent (1989) and Evans (1989) show that a high-quality seller will adopt a strategic delay in completing the bargain with the objective of signaling its higher quality

3. We thank Avron Barr and Shirley Tessler (Co-Directors, Stanford Computer Industry Project) and Professors David Yoffie and Mohanbir Sawhney for their many useful comments and suggestions.

to the uninformed buyer. An important distinction is that in these models, unlike in our model, the seller offers full quality at the beginning of the bargain itself though the transaction is not completed immediately. In that sense, time rather than quality distortion is the underlying signaling mechanism and their intuition is similar to Admati and Perry (1987). Moreover, an important driver of their result is the difference in the discount factor between the buyer and the seller which is not the case in our model.

1.2 A Brief Overview of the Model, Main Result and Intuition

We use a stylized model to analyze the marketing strategy implications of demand externality. We assume that the firm is *exogenously* endowed with a certain market potential (demand externality) and that this information is *not common knowledge* (i.e., the firm knows the demand potential through pre-launch market research, but, consumers are initially uncertain). The initial analysis assumes that consumers are homogeneous in their product valuation. The product-market exhibits network externality. Thus, a customer's utility for a product increases with the number of adopters of the product. To create a richer strategy space for the firm as well as the consumers, a two-period model is utilized. This formulation allows consumers the option of product adoption in either period, or no adoption at all. It gives the firm the flexibility to market the product and sequentially launch upgrades to allow consumers to increase their product quality. The multi-period setting also allows investigation of the dynamic effects of network externality on marketing strategy. The model is then extended to consider heterogeneity in consumer valuation of quality.

The central message is that a sequential introduction strategy featuring a new product with less-than-full quality in the first period followed by an upgrade serves as a credible signal of high network externality. Thus, if the firm's product enjoys high potential demand (high externality benefits), it follows a sequential product introduction strategy with appropriate prices and qualities, while if the network externality is low, the firm offers a product in the first period and there is no provision of upgrades. The optimality of the signaling strategy rests on the ability of the firm to provide, and of the consumers to consume, quality in a piece-meal fashion. Our later analysis in the context of consumer heterogeneity reinforces this intuition.

The intuition behind the signaling strategy is as follows. Any low-externality firm that mimics the high-externality firm's strategy to avoid detection faces complete revelation of the externality information at the beginning of the second period.⁴ Hence, the low-externality firm's gain from mimicking is limited only to the first period. Consequently, the thrust of the high-externality firm's strategy to prevent mimicking is to make imitation as costly as possible in the first period. To do so, *the high-externality firm shifts quality provision to the second period (or withholds the provision of quality in the initial period)*. Note that when

4. Actual sales at the end of the first period will credibly inform the consumer of demand potential for the product (such information is routinely available in trade journals).

externality is known with certainty, the optimal strategy for both the high- and the low-externality firm is provision of full quality in the first period. The high-type firm therefore foregoes the ability to provide quality and charge a price for the benefit of product consumption in the first period. Obviously, the mimicking low-externality firm suffers a similar opportunity loss. However, in the second period, the externality information is revealed and the high-externality firm provides incremental quality through an upgrade (the low externality firm does not market an upgrade in the second period). In essence, the high-externality firm by postponing quality incurs an opportunity loss in first period but achieves opportunity gains in the second period. A low-type firm following the same strategy incurs an opportunity loss in the first without any gains due to revelation in the second period. In a market with heterogeneous consumers, this strategy of withholding quality initially further implies that the high-externality firm not only introduces a lower-than-full quality to the high-valuation consumers (the *experts*) initially and offers them an upgrade in the second period, but also postpones serving the low-valuation consumers (the *novices*) to the second period.

2. MODEL

Consider a firm that has just developed a new product. Consumers are interested in the purchase of a single unit of this product. The per-period utility that a consumer derives from the product is dependent on the quality of the product, q , and the number of consumers using the product in that period, D and is given by

$$u(q, D) \equiv (\theta + bD^\alpha) q \quad \text{where } b, \alpha > 0. \quad (1)$$

When $b=0$, there is no network externality effect for the product and our model almost collapses to Moorthy (1984). Consistent with prior literature, the cost of quality is assumed to be convex and given by cq^2 where $c > 0$. Without loss of generality, we set $b=1$ and $\alpha = 1$ in the analysis that follows. We assume that consumers are identical with respect to the valuation of externality benefits.

2.1 Discussion of Key Model Assumptions

We make the following assumptions regarding asymmetric information and the specification of network externality:

ASSUMPTION 1: Asymmetric Information About Network Externality

As motivated earlier, information on potential demand may differ between the firm and consumers. The firm, through pre-launch market research, may have a better estimate of demand potential than the

potential consumers/observers/analysts.⁵ We operationalize information asymmetry by assuming that the firm knows the demand potential with certainty whereas consumers are uncertain about it and have a prior distribution over the possible externality type (i.e., demand potential) of the firm. Our modeling of asymmetric information in terms of consumer uncertainty about externality is essentially a representation of consumer uncertainty about reservation price for a product.

ASSUMPTION 2: Specification of Network Externality

We consider a situation where the demand for the product may be high (market potential = D_H) or low (market potential = D_L). We assume that all consumers have identical prior beliefs and use $\rho \in (0,1)$ to denote consumer's prior probability of a firm being the high-externality firm. Let $\rho = \Pr(D_j = D_H)$ and $1 - \rho = \Pr(D_j = D_L)$ denote the (pessimistic) prior belief of the consumers about the expected market potential, \bar{D} , given by $\bar{D} = \rho D_H + (1 - \rho) D_L$ and let $\underline{\rho}$ denote the posterior belief about D_j . The modeling of asymmetric information is consistent with prior work on signaling in marketing (e.g., Chu, 1992; Desai and Srinivasan, 1995).

2.2 Consumers Homogenous in Quality Valuation

Let the market consist of D_j consumers who are homogeneous with respect to their valuation of quality (and hence in their marginal willingness-to-pay for quality). Let θ denote the identical marginal willingness-to-pay for quality. The extent of the externality benefit enjoyed by an individual consumer will depend on the installed base of the product (since consumers are identical, for any given quality-price pair (q, p) , either all or none of the consumers will buy the product). We assume that the potential installed base of the product, D_j , can be either high, D_H , or low, D_L , with $D_H > D_L > 0$. The per-period utility derived by a consumer from using a product of quality q_j and with an associated installed base D_j for periods 1 and 2 respectively are given by $u_{1j}(q_j, D_j) = (\theta + D_j)q_j$, and $u_{2j}(q_j, D_j) = k(\theta + D_j)q_j$ where $k \geq 1$.

This specification of second period utility allows for variation in consumption benefits over time. Period 1 refers to the phase where consumers are *ex ante* uncertain about the potential installed base of the product while period 2 refers to the phase when consumers, by observing the past sales, have inferred the

5. For instance, Apple was launched by Jobs and Wozniak on the basis of their expectations about the size of the hobbyist market for personal computers. The business press in marked contrast was quite pessimistic about this market potential. Similarly, Apple's entry into the desktop publishing market was based on its market research data and this was at a time when the desktop publishing market "...wasn't on anyone's pie chart as a defined market..." (McKenna, 1988). Convex Computer is another example of a company that developed a strategy based on its demand projections for the "mini-supercomputer" – a market segment deemed non-existent in 1984 by industry participants and observers (McKenna, 1991).

true externality benefit associated with the product. The second phase could therefore represent a single period or the remaining usable life of a product. In particular, if consumer learning about the demand potential (and hence uncertainty resolution regarding externality benefit) occurs quickly (as compared to the usable life of the durable good), then $k \gg 1$.⁶

2.2.1 Product and Pricing Strategies under Complete Information

In this section, we assume that the consumers are aware of the externality benefits, D_j , associated with the product (i.e., there is no information asymmetry). Let q_{1j} and p_{1j} denote the quality and price respectively of the product introduced by the j -type firm, $j \in \{H,L\}$, in period 1. Similarly, let q_{2j}^e and p_{2j}^e be the expected quality and price of the upgrade, if any, introduced by the j -type firm, in period 2. Further, let q_{2j}^* and p_{2j}^* denote the optimal quality and price of the upgrade introduced by firm j , given first-period quality and price q_{1j} and p_{1j} . The product introduction problem faced by firm j is formalized as program P1 in Table 1.

Constraints (P1.2) and (P1.3) embody the participation or individual rationality (IR) conditions. Essentially, constraint (P1.2) requires that consumers, who have rational expectations about the quality and price of the upgrade, must get (expected) non-negative surplus by consuming the first-period product and the upgrade. Constraint (P1.3) requires that for consumers to buy an upgrade in period 2, they must derive non-negative surplus from the upgrade.

Equation (P1.4) embodies the sub-game perfection requirement that the quality and price of the upgrade offered by the high-externality firm in the second period must maximize its second-period profit, conditional on the first-period quality and price decisions. Equation (P1.5) is the rational expectation constraint for the consumers which requires that, while forming expectations about future qualities and prices, the consumers must recognize that, because of lack of commitment, the high-externality firm will select the second-period quality and price of the upgrade so as to maximize second-period profits.

The following proposition characterizes the optimal qualities, prices and profits of firm under complete information.⁷

Proposition 1: *When externality is known with certainty, firm j , $j \in \{H,L\}$, introduces "efficient" quality⁸ in the first period and does not introduce any upgrades in the second period. The optimal first-period quality, price and profits are higher for the H-type than for the L-type firm.*

6. We thank an anonymous reviewer for alerting us to this aspect of the utility formulation.

7. Proofs of all the propositions are given in the Appendix.

The complete characterization of equilibrium qualities, prices and profits for the *H*- and *L*-type firms are presented in Table 5. The intuition behind full provision of quality in the first period (and consequently, non-introduction of any upgrade in the second period) is as follows. The marginal cost of quality to the firm, $c > 0$, is the same whether an incremental unit of quality is provided in the first or the second period (for expositional simplicity, we ignore discounting). However, the marginal revenue from the incremental quality provision in the first period is strictly greater than marginal revenue from the second period (as the firm can extract premium for the first-period consumption benefit). Hence, the optimal strategy for the firm is to introduce a single product in the first period with efficient quality level. The strategy is the same whether the firm is an *H*-type or *L*-type firm (i.e., endowed with high or low demand externality).

2.2.2 Product and Pricing Strategies when Consumers are *ex ante* Uncertain about Externality

We now consider the case where consumers are *ex ante* (i.e., before observing the firm's product and pricing strategies) uncertain about the demand externality endowed with the product. However, the firm has private information about the demand for its product. The high-externality firm would prefer to convey this information to the consumers since it allows it to charge higher prices. The strategic question then is: how can the firm convey this information in a credible way through appropriate choice of the marketing mix elements?

We show that the firm's product introduction strategy can credibly signal the demand externality. In particular, a strategy of sequential product introduction featuring a new product and an upgrade helps consumers infer accurately the high demand externality. The key to the signaling strategy is the ability to provide (from the firm's perspective) and consume (from the consumer's perspective) quality in a piece-meal fashion. It is this aspect of the model that allows the high-type firm to postpone quality provision and thereby create a differential cost of signaling.

We obtain this result by employing the sequential equilibrium concept (Kreps and Wilson, 1982). Essentially, the concept requires that (a) each type of firm selects its optimal strategies given optimal action on the part of the consumers; (b) individual consumers make optimal buy/ no buy decisions given the optimal strategy of the firm; and (c) wherever possible consumers update their beliefs about the firm's type using Bayes' rule. The focus of our analysis is on the so-called *separating sequential equilibrium* in which the strategies of the two types differ and therefore, consumers are correctly informed about the firm's type. We further impose the requirement of "intuitive criterion" (Cho and Kreps, 1986) such that the high-type firm incurs the minimal signaling cost necessary to credibly separate. We refer to such an equilibrium as the least-cost sequential separating equilibrium.

8. By "efficient" quality, we mean the quality level that maximizes the difference between the consumer's valuation and the firm's marginal cost of quality.

We use the notation defined earlier in 2.2.1. Further, let $\Pi_t^{i,j}$ denote the profit earned in period t , $t \in \{1,2\}$, by a firm of “true” type i , $i \in \{H,L\}$, which is perceived by consumers to be of type j , $j \in \{H,L\}$. Note that i and j need not be the same; in fact, it is only in the separating equilibrium that $i = j$. Then, the least-cost separating equilibrium strategy, $(\tilde{q}_{1H}^{SE}, \tilde{p}_{1H}^{SE}, \tilde{q}_{2H}^{SE}, \tilde{p}_{2H}^{SE})$, for the H -type firm is obtained by solving program P2 formulated in Table 2.

Program P2 is analogous to program P1 except for the additional constraint (P2.6). Constraint (P2.6) represents the mimicking constraint. The logic behind the constraint is as follows. Consider the L -type firm’s options in period 1. It could either mimic the H -type firm’s first-period quality, q_{1H} , or, it could choose its complete-information strategy, q_{1L}^{CI} .⁹ If the L -type firm chooses the latter, it earns $\Pi_{Total}^{L,L,*}$, the L -type’s complete-information profits (which is equal to $\Pi_{Total}^{L,CI}$ given in Table 5). If, however, it mimics the H -type firm’s strategy in the first period, it will be perceived to be a H -type firm under the most favorable priors. The profit earned by the L -type in period 1 when it is erroneously perceived to be the H -type, denoted by $\Pi_1^{L,H}$ is given by

$$\Pi_1^{L,H} = D_L \left\{ (1+k)[\theta + D_H]q_{1H} - cq_{1H}^2 \right\}. \quad (2)$$

In the second period, however, the L -type’s “true” externality gets revealed. Thus, for the upgrade, the L -type can only extract premium for externality benefit consistent with D_L and the second-period profit earned by the L -type, denoted by $\Pi_2^{L,L}$, is given by

$$\Pi_2^{L,L} = D_L \left\{ k(\theta + D_L)q_{2L} - cq_{2L}^2 - 2cq_{1H}q_{2L} \right\} = D_L \left\{ \frac{k^2(\theta + D_L)^2}{4c} - k(\theta + D_L)q_{1H} + cq_{1H}^2 \right\}. \quad (3)$$

Thus, the total profit of the L -type under the mimicking option is $\Pi_{Total}^{L,H} = \Pi_1^{L,H} + \Pi_2^{L,L}$. Satisfaction of the constraint (P2.6) ensures that the L -type firm prefers to reveal its type information in the first period instead of mimicking, which is what we want in a separating equilibrium. Further, since the H -type firm aims to minimize the signaling cost, it implies that constraint (P2.6) is binding as otherwise the H -type firm can improve profit and continue to achieve separation.

The following proposition establishes the satisfaction of the Spence-Mirrlees “single-crossing” condition which is necessary for the existence of a separating equilibrium.

9. Any deviation from the H -type’s strategy will reveal to the consumers that the firm is L -type. Therefore, the L -type firm, when it deviates from the H -type firm, maximizes its profit by selecting its complete-information quality and price.

10. Even though consumers realize that they overpaid for the product in the first period, it is a *sunk cost* from their perspective and hence does not influence their buying decision regarding any upgrade provided by the L -type.

Proposition 2: When $k > (\theta + D_H)/D_L > 1$, the marginal losses resulting from any marginal downward distortion of first-period quality are greater for the low-externality firm than for the high-externality firm. Therefore, for first-period quality below the complete-information quality of the L-type, the L-type firm incurs greater losses than the H-type firm from any withholding of introductory quality, i.e.,

$$\frac{\partial \Pi_{Total}^{L,H}(D_L)}{\partial q_{1H}} \bigg/ \frac{\partial \Pi_{Total}^{H,H}(D_H)}{\partial q_{1H}} > 1 \text{ for } \forall q_{1H} \leq q_{1L}^{CI}. \quad (4)$$

The intuition behind the “single-crossing” condition for distortion in introductory quality is as follows. As is evident from equations (2) and (3), any shift in quality, Δq_{1H} , from period 1 to period 2 reduces the total profit of the L-type by $D_L[\theta + D_H + k(D_H - D_L)]\Delta q_{1H}$ while the corresponding reduction for the H-type firm is $D_H[\theta + D_H]\Delta q_{1H}$. Thus, any downward distortion in the first-period quality hurts the L-type firm more than the H-type firm when $k > (\theta + D_H)/D_L$.

The following proposition characterizes the unique least cost separating equilibrium strategies.

Proposition 3: In the least-cost separating equilibrium, the H-type firm introduces in the first period a new product with quality \tilde{q}_{1H}^{SE} which is lower than the complete-information first-period quality of the L-type, q_{1L}^{CI} , and hence lower than the complete-information first-period quality of the H-type, q_{1H}^{CI} . In the second period, the H-type introduces an upgrade with quality \tilde{q}_{2H}^{SE} such that the total quality provided by the H-type equals its complete-information quality, i.e., $\tilde{q}_{1H}^{SE} + \tilde{q}_{2H}^{SE} = q_{1H}^{CI}$. In contrast, the L-type firm follows its complete information strategy. When $k > (\theta + D_H)/D_L > 1$, the separating equilibrium exists and is supported by the off-equilibrium belief $q_1 \neq q_{1H}^{SE} \Rightarrow \underline{\rho} = 0$.

The complete characterization of the separating equilibrium strategies of the H- and L-type firms is presented in Table 5. The result demonstrates that a firm may, for strategic reasons, choose to underprovide quality (i.e., withhold quality) in the initial period and then make up the quality differential in the second period through provision of an upgrade. However, it is important to note that this emerges even though the firm has the ability to provide full (efficient) quality initially. There are other notable features of the signaling equilibrium. First, under-provision of introductory quality allows all consumers to correctly infer the demand externality associated with the product. Second, the H-type firm’s first period quality provision under signaling is lower than the L-type’s full information quality though the total quality provision (first- plus second-period quality) under signaling is the same as under complete information.

The basic thrust of the signaling strategy is consistent with the proposition of “giving the product away” initially to consumers to inform them of the value of the product and the associated externality, and then charging a premium for the upgrade.¹¹ The distortion in the first-period quality provision (i.e., withholding quality), Δq_{1H} , represents a source of the signaling cost borne by the H -type firm since the firm cannot extract first-period consumption benefit for Δq_{1H} . Now, in the separating equilibrium characterized in Proposition 3, the first period quality distortion as a fraction of the efficient quality level is given by

$$\frac{\Delta q_{1H}}{q_{1H}^{CI}} = \frac{q_{1H}^{CI} - \tilde{q}_{1H}^{SE}}{q_{1H}^{CI}} = \frac{(D_H - D_L)[(1+k)(\theta + D_H) + \theta + D_L]}{(\theta + D_H)^2 + k(D_H - D_L)(\theta + D_H)}, \quad (5)$$

$$\Rightarrow \frac{\partial [\Delta q_{1H}/q_{1H}^{CI}]}{\partial k} = \frac{(D_H - D_L)(\theta + D_H)[\theta + D_L]^2}{[(\theta + D_H)^2 + k(D_H - D_L)(\theta + D_H)]^2} > 0. \quad (6)$$

Thus, the fraction of quality withheld by the H -type firm to achieve credible separation increases as $k > 1$ increases. The intuition is that increase in k implies greater mimicking incentive for the L -type firm (recall that the L -type’s gain from mimicking H -type is $[k D_L(2+k)(D_H - D_L)(D_H + D_L + 2\theta)]/4c$). Thus, the requisite distortion to deter mimicking increases with k . This suggests that as the temporal variation in consumption benefit increases, the H -type’s “introductory” or “sampling” quality reduces and the firm earns greater proportion of its profits through the upgrade.

A measure of the “signaling cost” borne by the H -type in following the signaling strategy is the loss in profit under signaling relative to the H -type’s complete-information profits, i.e.,

$$\Delta \Pi_{H,Total}^{Signaling} \equiv \Pi_{Total}^H^{CI} - \Pi_{Total}^H^{SE} = \frac{k D_H (D_H - D_L)(\theta + D_H)[(1+k)(\theta + D_H) + \theta + D_L]}{2c[\theta + D_H + k(D_H - D_L)]}. \quad (7)$$

Thus, the loss in H -type’s profit due to signaling, as a fraction of the H -type’s complete information profit is given by

$$S_{CH}^{SE} \equiv \frac{\Delta \Pi_{H,Total}^{Signaling}}{\Pi_{Total}^H^{CI}} = \frac{2(D_H - D_L)[(1+k)(\theta + D_H) + \theta + D_L]}{(2+k)(\theta + D_H)[\theta + D_H + k(D_H - D_L)]}, \quad (8)$$

$$\Rightarrow \frac{\partial S_{CH}^{SE}}{\partial k} = - \frac{2(1+k)(D_H - D_L)^2(\theta + D_H)\{(1+k)(\theta + D_H) - 2(\theta + D_L)\}}{[(2+k)(\theta + D_H)\{\theta + D_H + k(D_H - D_L)\}]^2} < 0. \quad (9)$$

This implies that the signaling cost borne by the H -type firm to achieve credible separation from a possible ghost L -type firm decreases as the relative importance of second period consumption increases. This makes intuitive sense. The key element of the signaling strategy is the shifting of quality from period 1

11. We are grateful to an anonymous reviewer for this intuition.

to period 2 which means that the H -type firm forgoes its ability to charge for the first-period consumption. However, with the increase in second-period consumption utility, the loss in the marginal revenue per unit quality postponed to the second period decreases (even though the quality distortion increases; c.f. equation 6). In the limit, the profits from the signaling strategy approach the complete-information profits. This is consistent with the notion that “giving the product away” in the first period makes sense when majority of the firm’s profits are to be made in latter periods.

An alternative signaling mechanism for the H -type firm is to engage in *dissipative advertising* (“money burning”; see Milgrom and Roberts, 1986). Note that by mimicking the H -type’s complete information strategy, the L -type earns a profit of $\Pi_{Total}^{L,H} = [k D_L(2+k)(\theta+D_H)^2]/4c$ as compared to its complete information profit $\Pi_{Total}^{L,L} = [k D_L(2+k)(\theta+D_H)^2]/4c$. Thus, if the H -type expends

$$A_H \equiv \Pi_{Total}^{L,H} - \Pi_{Total}^{L,L} = [D_L k(2+k)(D_H - D_L)(D_H + D_L + 2\theta)]/4c, \quad (10)$$

as “introductory advertising”, along with introducing its complete-information quality, q_{1H}^* , the L -type has no incentive to mimic. However, observe that under “money burning”, the loss in H -type’s profit due to signaling through advertising, as a fraction of the H -type’s complete information profit is given by

$$SC_H^{MB} \equiv \frac{A_H}{\Pi_{Total}^{H,CI}} = \frac{D_L(D_H - D_L)[D_H + D_L + 2\theta]}{D_H(\theta + D_H)^2}, \quad (11)$$

which is independent of k .

We summarize the above discussion on the signaling costs under the two alternative signaling strategies – introductory quality distortion and introductory advertising – in the following proposition.

Proposition 4: *As the post-signaling valuation of the product increases (i.e., as $k \geq 1$ increases), separation through lowering introductory quality becomes cheaper. In contrast, the efficiency of dissipative advertising as a signal of high externality remains invariant to the post-signaling valuation.*

We demonstrate the properties of the separating equilibrium using a simple numerical example. We consider the following parameter values: $\theta = 0.5$; $D_H = 15$; $D_L = 12.5$; $c = 0.5$; and $k = 3$. The optimal quality, price and profit for the L -type firm under complete information are 39; 2,028; and, 15,843.75 respectively, and the corresponding quantities for the H -type firm are 45.5; 2,883; and, 27,028.13 respectively. The profits to the L -type firm from mimicking the H -type firm’s strategy in a separating equilibrium is 15,843.75. As is obvious, the L -type firm is indifferent between mimicking the H -type’s strategy and following its complete information strategy, which is the requirement of the least-cost separating equilibrium. The first period quality provision by the H -type firm in the signaling equilibrium is 22.04 which is lower than the H -type’s efficient level (of 45.5) as well as lower than the L -type’s efficient quality (of 39). The first-period price charged by the H -type in the signaling equilibrium is 1366.70. The

second period quality and price pair of the upgrade for the H -type firm is 24.45 and 1137.23, and the total profit to the H -type firm from signaling is 21,341.98. Note that the profits to the H -type firm from signaling exceed its profit if it were to mimic the L -type firm (which is 19,012.5). The numerical example also helps us explore the optimality of signaling through first-period quality distortion relative to money burning (dissipative advertising). For $k=3$, the signaling loss under signaling through withholding of quality is 5686.14 which is less than the corresponding loss for dissipative advertising (of 6678.65). Figure 1 charts the signaling loss under these two strategies as a function of k . Consistent with equation (9), the signaling loss to the H -type under quality signaling (expressed as a % of its complete-information profits) decreases with k while under dissipative advertising this loss remains constant (which is consistent with equation 11). Thus, as k increases, the relative efficiency of signaling through withholding introductory quality (compared to signaling through dissipative advertising) increases. Figure 2 plots H -type's introductory quality as a function of k . It is observed that as k increases, the introductory quality decreases.

We consider next the more general case where consumers are heterogeneous in their valuation of product quality. We consider consumer heterogeneity for two important reasons. First, heterogeneity permits a more realistic and richer description of consumers. Second (and this is getting ahead of the results), incorporating consumer heterogeneity allows us to demonstrate that the signaling strategy of lowering introductory quality in the context of heterogeneous market also implies, under certain parametric conditions, sequential targeting of consumer segments wherein the high-externality firm postpones serving the low-valuation segment to the post-signaling period.

2.3 Heterogeneity in Consumer Quality Valuation

As earlier, consumers obtain per period consumption benefits and are assumed to be identical in their valuation of network externality. Consumers now differ in their valuation of the quality of the product. We consider the case where the market is made up of two different types of consumer: an *expert* segment, with marginal valuation for quality θ_E , and a *novice* segment, with marginal valuation for quality θ_N . We assume that for a product with a given quality level, an expert user derives greater benefit from the product than a novice user, i.e., $\theta_E > \theta_N > 0$ (e.g., Moorthy and Png, 1992).¹² We denote the proportion of expert consumers by r_E and the proportion of novice consumers by $r_N \equiv 1 - r_E$ and this is assumed to be common knowledge.

12. This two-segment conceptualization is for analytical tractability. This results in a staircase demand function for the firm. A more general downward sloping demand specification obtained by assuming a uniform distribution of θ will not qualitatively change our results.

2.3.1 Introduction Strategy with Complete Information under Consumer Heterogeneity¹³

Let (q_{1E}^j, p_{1E}^j) and (q_{1N}^j, p_{1N}^j) denote the qualities and prices of the versions, if any, introduced by the j -type firm, $j \in \{H, L\}$, in period 1, targeted at the experts and the novices respectively. Similarly, let $(q_{2E}^{j\epsilon}, p_{2E}^{j\epsilon})$ and $(q_{2N}^{j\epsilon}, p_{2N}^{j\epsilon})$ be the expected qualities and prices of the second-period upgrades, if any, targeted at the experts and the novices, respectively. Further, let q_{2E}^{j*} and q_{2N}^{j*} denote the optimal qualities of the upgrades, if any, targeted at the experts and the novices respectively, given firm j 's first-period product products $(q_{1E}^j, p_{1E}^j; q_{1N}^j, p_{1N}^j)$ and let p_{2E}^{j*} and p_{2N}^{j*} similarly denote the optimal prices for the upgrades. The segmentation problem faced by firm j is formalized as program P3 in Table 3.

Constraints (P3.2)-(P3.5) are the participation constraints and are analogous to constraints (P1.2)-(P1.3) in program P1. Constraint (P3.6) is the self-selection or incentive compatibility (IC) constraint for the expert segment. The logic behind the constraint formulation is as follows. In the first period, experts face a choice between the base versions: version E with quality q_{1E}^j priced at p_{1E}^j and version N with quality q_{1N}^j priced at p_{1N}^j . Further, they also rationally anticipate firm j to introduce, if at all, upgrade E with quality $q_{2E}^{j\epsilon}$ priced at $p_{2E}^{j\epsilon}$ and version N with quality $q_{2N}^{j\epsilon}$ priced at $p_{2N}^{j\epsilon}$. We assume that an upgrade works only in combination with the appropriate base unit (i.e., if a consumer buys base version E in period 1, he can only buy upgrade E in period 2). Therefore, in period 1, the experts essentially face a choice between two consumption sequences: q_{1E}^j followed by $q_{2E}^{j\epsilon}$ or q_{1N}^j followed by $q_{2N}^{j\epsilon}$. Constraint (P3.6) requires that if base version q_{1E}^j is targeted at the expert segment, then the experts must derive a higher surplus by buying the base version E and upgrade E than by buying base version N and upgrade N . Note that the IC constraint for novices, i.e.,

$$(1+k)(\theta_N + D_j)q_{1N}^j + k(\theta_N + D_j)q_{2N}^{j\epsilon} - p_{1N}^j - p_{2N}^{j\epsilon} \geq (1+k)(\theta_N + D_j)q_{1E}^j + k(\theta_N + D_j)q_{2E}^{j\epsilon} - p_{1E}^j - p_{2E}^{j\epsilon}, \quad (12)$$

13. Strictly speaking, "complete information" is a misnomer. Even though there is no information asymmetry between the firm and the consumers regarding externality, there exists information asymmetry between the consumers and the firm regarding marginal valuation of quality: individual consumers know their θ while the firm does not. In technical terms, while there is no signaling, there is adverse selection problem.

is redundant since it can be shown that if the IC constraint for the experts (equation P3.6) is binding, then the IC constraint for the novices (equation 12) is strictly satisfied and hence is a slack or non-binding constraint.¹⁴ Constraints (P3.7)-(P3.9) are analogous to constraints (P1.4)-(P1.6) in program P1.

The following proposition characterizes firm j 's optimal product introduction strategy in a heterogeneous market when consumers *ex ante* know the externality benefit associated with the product.

Proposition 5: *When $r_E < (\theta_N + D_j) / (\theta_E + D_j) < 1$, firm j follows “simultaneous introduction strategy” wherein it introduces two versions in the first period targeted at the experts and the novices segment and does not introduce any upgrade in the second period. If, however, $1 > r_E > (\theta_N + D_j) / (\theta_E + D_j)$, the firm does not serve the novice segment at all. A “sequential introduction strategy” wherein the firm postpones serving the novice segment to the second period is never optimal.*

The complete characterization of the equilibrium strategies is presented in Table 6. Due to heterogeneity in consumer valuation for quality, the firm faces a cannibalization problem: to ensure that the expert consumers indeed buy the high-quality version q_{1E}^j targeted at them rather than buying the low-quality version q_{1N}^j targeted at the novices, the firm has to leave sufficient surplus with the expert consumers. When $r_E < (\theta_N + D_j) / (\theta_E + D_j)$, the proportion of novices is not “small enough” for the firm to ignore serving this segment. However, when $r_E > (\theta_N + D_j) / (\theta_E + D_j)$, the firm is better off by not serving the novices because, under this parametric condition, the additional profits earned from serving the novices is outweighed by the surplus left with the experts, i.e.,

$$D_j r_N \frac{k^2 (\theta_N + D_j)^2}{4c} < D_j r_E \frac{k^2 (\theta_E - \theta_N) (\theta_N + D_j)}{2c}. \quad (13)$$

The results imply that, under complete information, there is no rationale for either a delay in the provision of quality (i.e., no need for upgrades) or a delay in targeting segments. Thus, the use of either of these (or both) must stem from information asymmetry on externality.

2.3.2 Introduction Strategy under Consumer Heterogeneity with Asymmetric Information

We now consider the general case where we allow for information asymmetry arising from consumer uncertainty about the demand potential for the product. There are two key insights derived from the analysis of the H -type's signaling strategy: (a) As in the homogenous case, shifting quality provision to the second period (i.e., withholding the provision of quality in the initial period) continues to constitute a credible mechanism to signal high externality; and, (b) To deter mimicking, the H -type postpones serving the novice

14. A formal proof is available with the authors on request.

segment since downward distortion in the quality of the novices' version (q_{1N}^H) hurts the L -type (relative to the H -type) more than quality distortion of the expert's version (q_{1E}^H).

We use the notations defined in 2.3.1. Further, let $\Pi^{i,j}$ denote the profit earned in period t , $t \in \{1,2\}$, by a firm of "true" type i , $i \in \{H,L\}$, which is perceived by consumers to be of type j , $j \in \{H,L\}$. Note that i and j need not be the same; in fact, it is only in the separating equilibrium that $i = j$. Then, the separating equilibrium strategy, $(\bar{q}_{1E}^{H,SE}, \bar{p}_{1E}^{H,SE}; \bar{q}_{1N}^{H,SE}, \bar{p}_{1N}^{H,SE}; \bar{q}_{2E}^{H,SE}, \bar{p}_{2E}^{H,SE}; \bar{q}_{2N}^{H,SE}, \bar{p}_{2N}^{H,SE})$, for the H -type firm is obtained by solving the program P4 formulated in Table 4.

Program P4 is analogous to program P3 except for an additional constraint (P4.9). Constraint (P4.9) is the mimicking constraint and requires that in a separating equilibrium the L -type, by following its complete-information strategy, earns at least as much total profit as by mimicking the H -type's signaling strategy. This is analogous to constraint (P2.6) in program P2 and, as discussed earlier, is binding in the least-cost separating equilibrium.

The following proposition establishes the satisfaction of the "single-crossing" condition for the case of heterogeneous consumers. It further establishes that withholding introductory quality of the novices' version is a more efficient signal as compared to withholding quality of the experts' version.

Proposition 6: *When $k > (\theta + D_H)/D_L > 1$, the marginal losses resulting from any marginal downward distortion of first-period quality of either experts' or novices version are greater for the low-externality firm than for the high-externality firm, i.e.,*

$$\frac{\partial \Pi_{Total}^{L,H}(D_L)}{\partial q_{1E}^H} \bigg/ \frac{\partial \Pi_{Total}^{H,H}(D_H)}{\partial q_{1E}^H} > 1 \quad \text{and} \quad \frac{\partial \Pi_{Total}^{L,H}(D_L)}{\partial q_{1N}^H} \bigg/ \frac{\partial \Pi_{Total}^{H,H}(D_H)}{\partial q_{1N}^H} > 1. \quad (14)$$

Further, withholding the quality of the novices' base version hurts the L -type more (relative to the H -type) than withholding the quality of the experts' base version, i.e.,

$$\frac{\partial \Pi_{Total}^{L,H}(D_L)}{\partial q_{1N}^H} \bigg/ \frac{\partial \Pi_{Total}^{H,H}(D_H)}{\partial q_{1N}^H} > \frac{\partial \Pi_{Total}^{L,H}(D_L)}{\partial q_{1E}^H} \bigg/ \frac{\partial \Pi_{Total}^{H,H}(D_H)}{\partial q_{1E}^H} \quad \text{for } \forall q_{1N}^H, \forall q_{1E}^H. \quad (15)$$

The intuition behind the differential cost of first-period quality distortion (equation 14) is similar to that for the case of homogeneous consumers (see the discussion in section 2.2.2). Therefore, it follows that distortion in the first-period quality provision will be a feature of the signaling equilibrium under consumer heterogeneity as well. The important question then is: should the H -type firm lower the first-period quality provision to the experts or novices or both? The second part of the proposition in equation (15) answers this question. The H -type firm deters mimicking by the L -type firm by distorting quality provision to the novice segment before distorting the initial quality provided to the experts. The intuition behind this order

relationship in distortion of quality is as follows. Note that the loss resulting from this shifting of quality from period 1 to period 2 arises from the firm's inability to extract the surplus from first-period consumption. Since the marginal valuation for quality (and hence the magnitude of first-period consumption utility) is higher for the experts as compared to the novices, the loss in marginal revenue to the H -type firm resulting from a marginal distortion in first-period quality is lower for the novice segment than for the expert segment.

The following proposition characterizes the least-cost separating equilibrium strategies of the high- and the low-externality firms in the presence of consumer heterogeneity.

Proposition 7: *In the least-cost separating equilibrium, in the first period, the H -type firm introduces a less-than-efficient quality to the experts and does not serve the novice segment. In the second period, the H -type firm introduces an upgrade targeted at the experts and a new release, targeted at the novices. In contrast, the L -type follows its complete information strategy of simultaneous product introduction. When $k > \frac{\theta_E + D_H}{D_L} > 1$, the separating equilibrium exists and is supported by the off-equilibrium belief*

$$q_{1E} \neq \bar{q}_{1E}^{H SE} \text{ or } q_{1N} \neq \bar{q}_{1N}^{H SE} \Rightarrow \underline{\rho} = 0.$$

The complete characterization of the separating equilibrium strategies of the H - and the L -type firms is given in Table 6. The result demonstrates that a firm may, for strategic reasons, choose not to serve low-valuation segment and under-provide quality to high-valuation segments in the initial period and then make up the quality differential in the second period through provision of an upgrade and a new release. Note that even though the H -type firm does not serve the novices and under-provides introductory quality to the experts in the first period, the total quality provided to the experts as well as the novices are the same as the complete-information efficient quality, i.e., $\bar{q}_{1E}^{H SE} + \bar{q}_{2E}^{H SE} = q_{1E}^{H CI}$ and $\bar{q}_{2N}^{H SE} = q_{1N}^{H CI}$. Thus, signaling merely entails shifting of quality from period 1 to period 2. This is analogous to the result for the case of homogeneous consumers (c.f. Proposition 3). The heterogeneity analysis, in addition to reinforcing the earlier intuition about withholding of quality, highlights the strategic role of sequential targeting of segments in conveying private information about network externality.

We illustrate the separating equilibrium strategies in the case of heterogeneous consumers using the following set of parameters: $\theta_E = 8.0$; $\theta_N = 2.5$; $D_H = 15$; $D_L = 10$; $c = 0.5$; $r_E = 0.4$; $r_N = 0.6$; and $k = 3$. The H -type firm's simultaneous introduction strategy features two products in period 1: a version for the experts with quality 69 and price 5193; and a version for novices with quality 52.5 and price 3675 which yields a total profit of 37,546. The corresponding values for the L -type are: experts' version – quality 54 at price 3068 and novices' version – quality 37.5 at price 1875, yielding a total profits of 13,451.25. The profits to the L -type firm from mimicking the H -type firm's is 13451.25. As is obvious, the L -type firm is

indifferent between mimicking the H -type's strategy and following its complete information strategy, which is the requirement of the least-cost separating equilibrium. The first-period quality provision by the H -type firm in the signaling equilibrium is 52.33 which is lower than the H -type's efficient level (of 69) as well as the L -type's efficient level (of 54). Note, however, that it is not necessary that the separating equilibrium quality provided to the experts in period 1 be less than the L -type's efficient level. This is so only when either k or/and r_E are 'large' so that the L -type's mimicking incentive is high to necessitate so much quality withholding. The quality of the upgrade offered to the experts in period 2 is 16.67 (priced at 1150.08) while the quality of the new release targeted at the novices is 52.50 (priced at 2756.25). The total profit earned by the H -type under signaling is 28,710.47 which exceeds H -type's profit if it were to mimic the L -type's strategy (which is 20,176.88). For $k=3$, the signaling loss due to withholding of introductory quality is 8,836.40 which is less than the signaling loss due to money burning (of 11,580). Figure 3 charts the signaling loss under signaling through quality distortion and dissipative advertising. As in the homogeneous case (c.f. Figure 1), the signaling cost borne by the H -type firm decreases as the relative importance of second-period consumption (i.e., k) increases. Figure 4 plots H -type's introductory quality provision to the experts (as a fraction of the efficient complete-information quality level), as a function of k at three values of r_E , the proportion of experts. Again, as in the homogeneous case (c.f. Figure 2), the introductory quality decreases as $k > 1$ increases due to greater mimicking incentive for the L -type firm necessitating greater quality distortion. Similarly, the distortion in introductory quality is increasing with r_E because larger proportion of experts implies higher gains for the L -type from mimicking.¹⁵ Thus, the basic intuition behind signaling through withholding of quality is robust to consumer heterogeneity.

The findings of this paper provide a basis for rationalizing the product introduction strategy commonly observed in high-technology product markets. A new product launch followed by releases and upgrades is the rule in these markets. Our theory suggests that the launch of a single product targeted at a specific segment (e.g., the expert segment) in the first period instead of a product line (targeted at the different segments) is in response to informational asymmetry. Viewed from this perspective, the model predicts that a firm will postpone the provision of quality to later periods even when it has access to all possible levels of quality at the beginning of the game. In other words, the firm may not enter the market with the highest quality product in the initial period. The product introduction strategy of Motorola for its PowerPC line of chips provides an illustrative example. Motorola had access to and had perfected the production/design of the PowerPC 601, 603, 604 and 620 line of microchips. However it strategically chose to enter the market with the PowerPC 601 line of chips with 50 MHz cycle time and introduced the high-end line (PowerPC 601

15. If k and/or r_E is sufficiently large, the introductory quality introduced to the experts will be lower than the quality of the new release offered to the novices in period 2. For example, in the above numerical example, the introductory quality to the experts is 52.33 while the quality of the new release (offered to the novices in period 2) is 52.5. Of course, the total quality offered to the experts (through the first-period new product and the second-period upgrade) exceeds the total quality provided to the novices.

chip in 66 MHz and 80 MHz cycle time and PowerPC 603 in 66 MHz and 80 MHz cycle time) later (*Computerworld*, 1994).¹⁶

Another implication of the model is that the later releases of the product would focus more on the usability dimension of product quality as it is the novice segment to whom the later versions are targeted. This seems to be consistent with the trend in application software. For instance, the central theme of the advertisements for Excel 5.0 and Oracle7 Workgroup Server is the user-friendliness of these versions. The core benefit proposition for new versions of Quicken is ease of use.

3. SUMMARY AND DISCUSSION

Network externality refers to the phenomenon where the benefit to a consumer from adoption and use of the product increases with the number of users of the product. The effects are observed in a wide range of product markets and are particularly important in the high-technology product market. We focus in this paper on highlighting the role of product introduction strategy in influencing consumer expectations about the demand externality effects for a new product. Our analysis demonstrates that consumer knowledge about the network externality associated with a product (or the lack of such knowledge) has a significant bearing on the new product strategy of the firm. In particular, firms earn a higher profit with a one-shot new product introduction strategy when consumers are informed about the demand externality associated with a product. Conversely, sequential introduction of products is the optimal strategy when consumers are not informed about the demand externality associated with a product. The implementation of the sequential strategy is through the use of upgrades (and new releases as well in the case of heterogeneous markets). The sequential product introduction strategy credibly informs consumers about the magnitude of externality effects and creates the right consumer expectations about the new product. The theory offers a rationalization for the strategy of new products, releases and upgrades. More importantly, it demonstrates the importance of a unique institutional feature of technology markets (namely, the ability to provide and consume quality in a piece-meal fashion) in resolving information asymmetry issues in the context of new product introductions.

New products, upgrades and new releases are a common phenomenon in the technology market and it is far too rich and complex to be adequately captured in a single model. We view this theory as a first step in understanding the phenomenon and hope that further research will illumine other theories and lead to additional insights. There are already several perspectives on this issue in the business press. For instance, it is commonly recognized that the software market faces rapid technological change. Therefore, there is a constant pressure to introduce products as early as possible since later introduction raises the specter of obsolescence. As a consequence, it is not uncommon to introduce even products with bugs and rely on

16. The caveat that competing explanations may exist readily applies here. Unfortunately, there is little data available in the public domain to help parcel out the various forces driving sequential introduction.

upgrades to eliminate them or improve quality further (*Investor's Business Daily*, September 5, 1996). The Internet provides another setting for the upgrade phenomenon where it goes under the label of "dribbleware" (*Wall Street Journal*, August 8, 1996). Dribbleware refers to the practice wherein updates to application programs are sent out on a continual basis over the Internet. The rationale for dribbleware is that the Internet provides free testing abilities for a firm in hard-to-duplicate environments along with a head start in converting users (and for users it represents an opportunity to get the latest software, often for free). The alternative perspectives discussed above represent more compelling rationalization for the phenomenon when markets do not exhibit information asymmetry.

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**Table 1: Product Introduction when Externality is Known (Homogenous Case):
Formulation of Program P1**

$$q_{1j}^{CI}, p_{1j}^{CI} \in \arg \max_{q_{1j}, p_{1j}} \Pi_1^j(q_{1j}, p_{1j}) + \Pi_2^j(q_{2j}^*, p_{2j}^* | q_{1j}, p_{1j}) \quad (P1.1)$$

subject to

$$(1+k)[\theta + D_j]q_{1j} + k(\theta + D_j)q_{2j}^e - p_{1j} - p_{2j}^e \geq 0, \quad (P1.2)$$

$$k(\theta + D_j)q_{2j}^e - p_{2j}^e \geq 0, \quad (P1.3)$$

$$q_{2j}^*, p_{2j}^* \in \arg \max_{q_{2j}, p_{2j}} \Pi_2^j(q_{2j}, p_{2j} | q_{1j}, p_{1j}), \quad (P1.4)$$

$$q_{2j}^e = q_{2j}^* ; p_{2j}^e = p_{2j}^* , \quad (P1.5)$$

$$q_{1j} \geq 0; q_{2j} \geq 0; p_{1j} \geq 0; p_{2j} \geq 0. \quad (P1.6)$$

**Table 2: Product Introduction when Externality is *ex ante* Unknown (Homogenous Case):
Formulation of Program P2**

$$\bar{q}_{1H}^{SE}, \bar{p}_{1H}^{SE} \in \arg \max_{q_{1H}, p_{1H}} \Pi_1^{H,H}(q_{1H}, p_{1H}) + \Pi_2^{H,H}(q_{2H}^*, p_{2H}^* | q_{1H}, p_{1H}) \quad (P2.1)$$

subject to

$$(1+k)[\theta + D_H]q_{1H} + k(\theta + D_H)q_{2H}^e - p_{1H} - p_{2H}^e \geq 0, \quad (P2.2)$$

$$k(\theta + D_H)q_{2H}^e - p_{2H}^e \geq 0, \quad (P2.3)$$

$$q_{2H}^*, p_{2H}^* \in \arg \max_{q_{2H}, p_{2H}} \Pi_2^{H,H}(q_{2H}, p_{2H} | q_{1H}, p_{1H}). \quad (P2.4)$$

$$q_{2H}^e = q_{2H}^* ; p_{2H}^e = p_{2H}^* , \quad (P2.5)$$

$$\Pi_1^{L,H}(q_{1H}, p_{1H}) + \Pi_2^{L,L}(q_{2L}^*, p_{2L}^*) \leq \Pi_{Total}^{L,L}(q_{1L}^{CI}, p_{1L}^{CI}, q_{2L}^{CI}, p_{2L}^{CI}), \quad (P2.6)$$

$$q_{1H} \geq 0; q_{2H} \geq 0; p_{1H} \geq 0; p_{2H} \geq 0. \quad (P2.7)$$

**Table 3: Product Introduction when Externality is Known (Heterogeneous Case):
Formulation of Program P3**

$$q_{1E}^{jCI}, p_{1E}^{jCI}, q_{1N}^{jCI}, p_{1N}^{jCI} \in \arg \max_{q_{1E}^j, p_{1E}^j, q_{1N}^j, p_{1N}^j} \Pi_1^j(q_{1E}^j, p_{1E}^j, q_{1N}^j, p_{1N}^j) + \Pi_2^j(q_{2E}^{j*}, p_{2E}^{j*}, q_{2N}^{j*}, p_{2N}^{j*} | q_{1E}^j, p_{1E}^j, q_{1N}^j, p_{1N}^j) \quad (P3.1)$$

subject to

$$(1+k)(\theta_E + D_j)q_{1E}^j + k(\theta_E + D_j)q_{2E}^{j*} - p_{1E}^j - p_{2E}^{j*} \geq 0, \quad (P3.2)$$

$$k(\theta_E + D_j)q_{2E}^{j*} - p_{2E}^{j*} \geq 0, \quad (P3.3)$$

$$(1+k)(\theta_N + D_j)q_{1N}^j + k(\theta_N + D_j)q_{2N}^{j*} - p_{1N}^j - p_{2N}^{j*} \geq 0, \quad (P3.4)$$

$$k(\theta_N + D_j)q_{2N}^{j*} - p_{2N}^{j*} \geq 0, \quad (P3.5)$$

$$(1+k)(\theta_E + D_j)q_{1E}^j + k(\theta_E + D_j)q_{2E}^{j*} - p_{1E}^j - p_{2E}^{j*} \geq (1+k)(\theta_E + D_j)q_{1N}^j + k(\theta_E + D_j)q_{2N}^{j*} - p_{1N}^j - p_{2N}^{j*}, \quad (P3.6)$$

$$q_{2E}^{j*}, p_{2E}^{j*}, q_{2N}^{j*}, p_{2N}^{j*} \in \arg \max_{q_{2E}^j, p_{2E}^j, q_{2N}^j, p_{2N}^j} \Pi_2^j(q_{2E}^j, p_{2E}^j, q_{2N}^j, p_{2N}^j | q_{2E}^j, p_{2E}^j, q_{2N}^j, p_{2N}^j), \quad (P3.7)$$

$$q_{2E}^{j*} = q_{2E}^{j*}; p_{2E}^{j*} = p_{2E}^{j*}; q_{2N}^{j*} = q_{2N}^{j*}; p_{2N}^{j*} = p_{2N}^{j*}. \quad (P3.8)$$

$$q_{1E}^j \geq 0, p_{1E}^j \geq 0, q_{1N}^j \geq 0, p_{1N}^j \geq 0, q_{2E}^{j*} \geq 0, p_{2E}^{j*} \geq 0, q_{2N}^{j*} \geq 0, p_{2N}^{j*} \geq 0. \quad (P3.9)$$

**Table 4: Product Introduction when Externality is *ex ante* Unknown (Heterogeneous Case):
Formulation of Program P4**

$$\bar{q}_{1E}^{HSE}, \bar{p}_{1E}^{HSE}, \bar{q}_{1N}^{HSE}, \bar{p}_{1N}^{HSE} \in \arg \max_{q_{1E}^H, p_{1E}^H, q_{1N}^H, p_{1N}^H} \Pi_1^{H,H}(q_{1E}^H, p_{1E}^H, q_{1N}^H, p_{1N}^H) + \Pi_2^{H,H}(q_{2E}^{H*}, p_{2E}^{H*}, q_{2N}^{H*}, p_{2N}^{H*} | q_{1E}^H, p_{1E}^H, q_{1N}^H, p_{1N}^H) \quad (P4.1)$$

subject to

$$(1+k)(\theta_E + D_H)q_{1E}^H + k(\theta_E + D_H)q_{2E}^{H*} - p_{1E}^H - p_{2E}^{H*} \geq 0, \quad (P4.2)$$

$$k(\theta_E + D_H)q_{2E}^{H*} - p_{2E}^{H*} \geq 0, \quad (P4.3)$$

$$(1+k)(\theta_N + D_H)q_{1N}^H + k(\theta_N + D_H)q_{2N}^{H*} - p_{1N}^H - p_{2N}^{H*} \geq 0, \quad (P4.4)$$

$$k(\theta_N + D_H)q_{2N}^{H*} - p_{2N}^{H*} \geq 0, \quad (P4.5)$$

$$(1+k)(\theta_E + D_H)q_{1E}^H + k(\theta_E + D_H)q_{2E}^{H*} - p_{1E}^H - p_{2E}^{H*} \geq (1+k)(\theta_E + D_H)q_{1N}^H + k(\theta_E + D_H)q_{2N}^{H*} - p_{1N}^H - p_{2N}^{H*}, \quad (P4.6)$$

$$q_{2E}^{H*}, p_{2E}^{H*}, q_{2N}^{H*}, p_{2N}^{H*} \in \arg \max_{q_{2E}^H, p_{2E}^H, q_{2N}^H, p_{2N}^H} \Pi_2^{H,H}(q_{2E}^H, p_{2E}^H, q_{2N}^H, p_{2N}^H | q_{2E}^H, p_{2E}^H, q_{2N}^H, p_{2N}^H), \quad (P4.7)$$

$$q_{2E}^{H*} = q_{2E}^{H*}; p_{2E}^{H*} = p_{2E}^{H*}; q_{2N}^{H*} = q_{2N}^{H*}; p_{2N}^{H*} = p_{2N}^{H*}. \quad (P4.8)$$

$$\Pi_1^{H,H}(q_{1E}^H, p_{1E}^H, q_{1N}^H, p_{1N}^H) + \Pi_2^{L,L}(q_{2E}^{L*}, p_{2E}^{L*}, q_{2N}^{L*}, p_{2N}^{L*} | q_{1E}^L, p_{1E}^L, q_{1N}^L, p_{1N}^L) \leq \Pi_{Final}^{L,L}(q_{1E}^{LCI}, p_{1E}^{LCI}, q_{1N}^{LCI}, p_{1N}^{LCI}), \quad (P4.9)$$

$$q_{1E}^H \geq 0, p_{1E}^H \geq 0, q_{1N}^H \geq 0, p_{1N}^H \geq 0, q_{2E}^{H*} \geq 0, p_{2E}^{H*} \geq 0, q_{2N}^{H*} \geq 0, p_{2N}^{H*} \geq 0. \quad (P4.10)$$

**Table 5: Characterization of Equilibria for the Homogeneous Case
(Programs P1 and P2)**

Condition	Equilibrium Strategies
<i>Case I: Externality Known With Certainty (Proposition 1)</i>	$q_{1j}^{CI} = \frac{k(\theta + D_j)}{2c}; p_{1j}^{CI} = \frac{k(1+k)(\theta + D_j)^2}{4c}$ in period 1; and, $q_{2j}^{CI} = p_{2j}^{CI} = 0$ in period 2. $\Pi_{total}^{CI} = \Pi_j^{CI} = \frac{D_j k(2+k)(\theta + D_j)^2}{4c}$ for $j = \{H, L\}$.
<i>Case II: Externality ex ante Unknown (Proposition 3)</i>	<p><i>H-type's Separating Equilibrium qualities:</i></p> $\bar{q}_{1H}^{SE} = \frac{k(\theta + D_L)}{2c} \times \frac{\theta + D_L}{\theta + D_H + k(D_H - D_L)}$ in period 1; and, $\bar{q}_{2H}^{SE} = \frac{k(D_H - D_L)[(1+k)(\theta + D_H) + \theta + D_L]}{2c[\theta + D_H + k(D_H - D_L)]}$ in period 2. <p><i>L-type's Separating Equilibrium qualities:</i></p> $\bar{q}_{1L}^{SE} = \frac{k[\theta + D_L]}{2c}$ in period 1; and, $\bar{q}_{2L}^{SE} = 0$ in period 2.

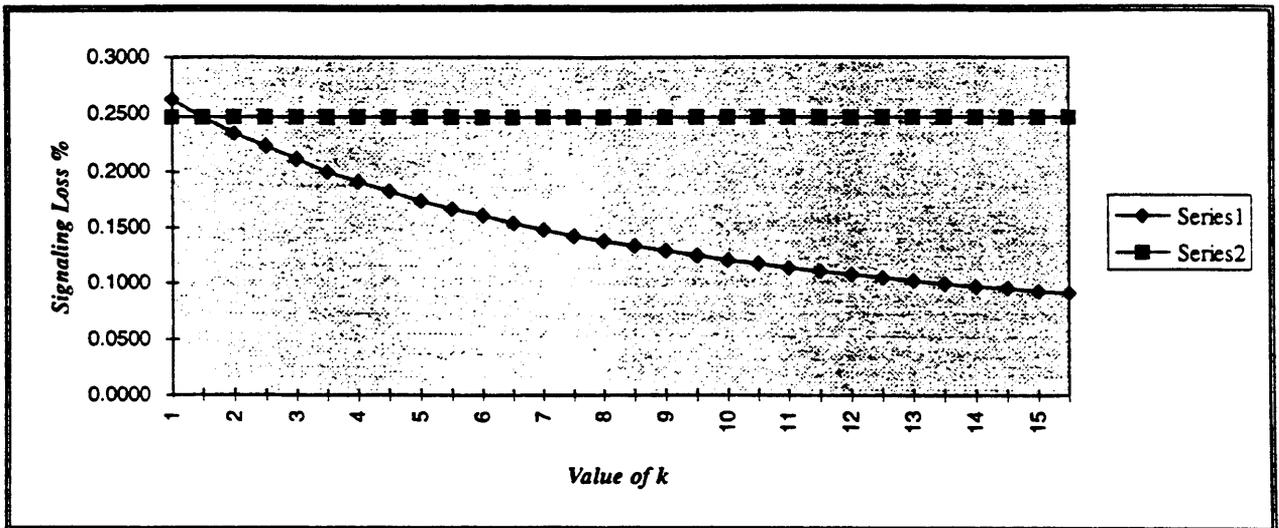
NOTE: The superscript *CI* refers to "complete information" while *SE* denote "(least-cost) separating equilibrium".

**Table 6: Characterization of Equilibria for the Heterogeneous Case
(Programs P3 and P4)**

Condition	Equilibrium Strategies
<i>Case I: Externality Known With Certainty (Proposition 5)</i>	$q_{1E}^{CI} = \frac{k(\theta_E + D_j)}{2c}; q_{1N}^{CI} = \frac{k(\theta_N + D_j)}{2c}$ in period 1; and, $q_{2E}^{CI} = 0; q_{2N}^{CI} = 0$ in period 2, for $j = \{H, L\}$.
<i>Case II: Externality ex ante Unknown (Proposition 7)</i>	<p><i>H-type's Separating Equilibrium qualities:</i></p> $\bar{q}_{1E}^{HSE} = \frac{k(\theta_E + D_H)}{2c} \times \frac{k(\theta_E - \theta_N)}{\theta_E + D_H + k(D_H - D_L)}$ $- \frac{k\{r_E(\theta_E - \theta_N)[k(\theta_N + D_L) - (\theta_E + D_L)] - (\theta_N + D_L)^2\}}{2cr_E[\theta_E + D_H + k(D_H - D_L)]};$ $\bar{q}_{1N}^{HSE} = \epsilon = 0$ in period 1; and, $\bar{q}_{2E}^{HSE} = \frac{k(\theta_E + D_H)}{2c} - \bar{q}_{1E}^{HSE}; \bar{q}_{2N}^{HSE} = \frac{k(\theta_N + D_H)}{2c}$ in period 2. <p><i>L-type's Separating Equilibrium qualities:</i></p> $\bar{q}_{1E}^{LSE} = \frac{k(\theta_E + D_L)}{2c}; \bar{q}_{1N}^{LSE} = \frac{k(\theta_N + D_L)}{2c}$ in period 1; and, $\bar{q}_{2E}^{LSE} = 0; \bar{q}_{2N}^{LSE} = 0$ in period 2.

NOTE: The superscript *CI* refers to "complete information" while *SE* denote "(least-cost) separating equilibrium".

Figure 1: Impact of k on the Efficiency of Signaling through Product Introduction & Signaling through Dissipative Introductory Advertising (Homogenous Consumers)



Series 1 = Signaling loss due to signaling through product introduction
 Series 2 = Signaling loss due to signaling through dissipative advertising (money burning)

Figure 2: Distortion in H -type's Introductory Quality as a function of k (Homogenous Consumers)

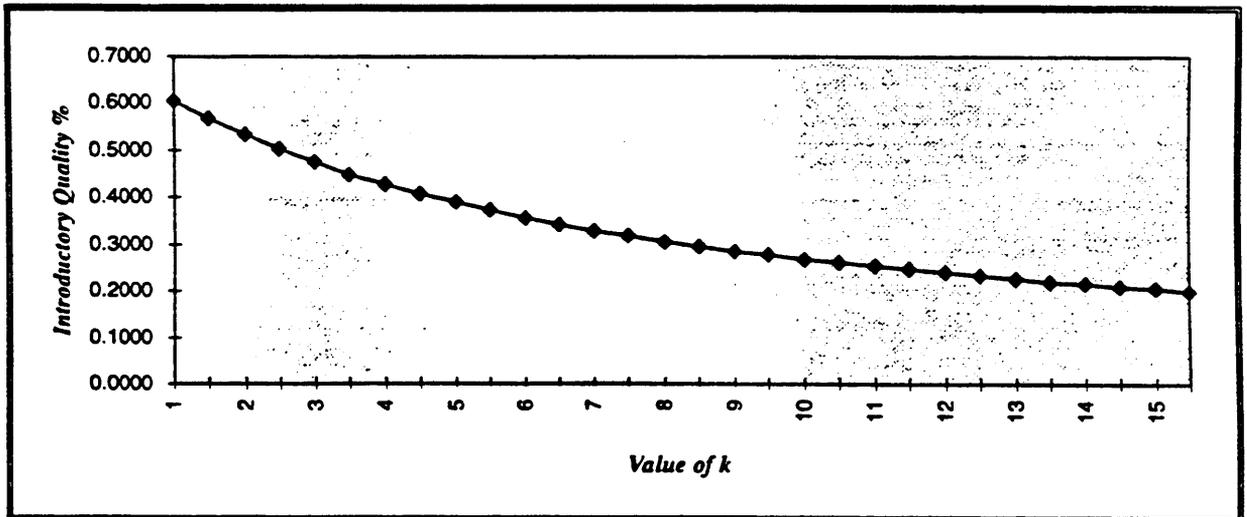
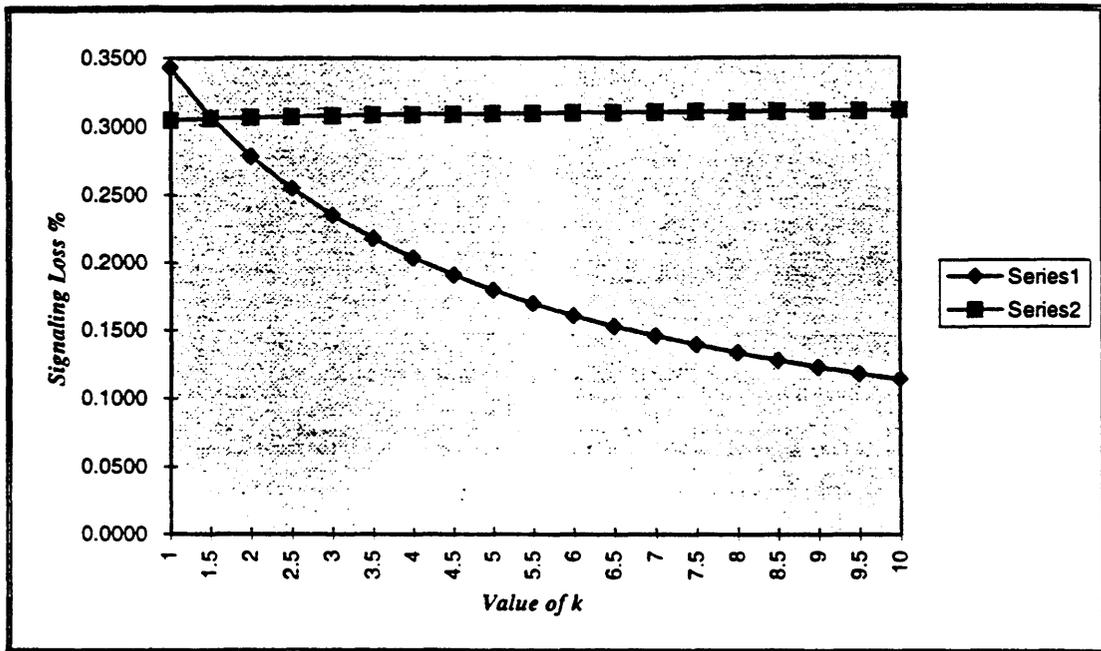
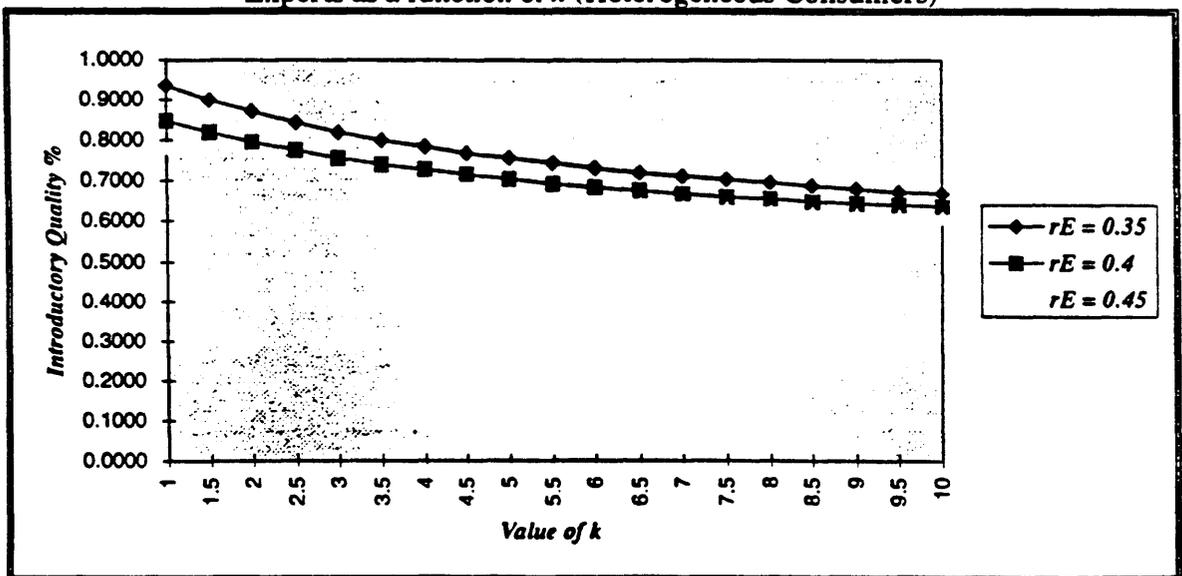


Figure 3: Impact of k on the Efficiency of Signaling through Product Introduction & Signaling through Dissipative Introductory Advertising (Heterogeneous Consumers)



Series 1 = Signaling loss due to signaling through product introduction
 Series 2 = Signaling loss due to signaling through dissipative advertising (money burning)

Figure 4: Distortion in H -type's Introductory Quality to the offered Experts as a function of k (Heterogeneous Consumers)



APPENDIX

Proof of Proposition 1:

Consider the maximization problem facing firm j in period 2. Given that the IR constraint for the upgrade (equation P1.3 in program P1) is binding, the firm's problem is

$$\max_{q_{2j}} \Pi_2^j(q_{2j}|q_{1j}, p_{1j}) \equiv D_j \left[k(\theta + D_j)q_{2j} - cq_{2j}^2 - 2cq_{1j}q_{2j} \right]. \quad (A1)$$

$$\Leftrightarrow q_{2j}^* = \frac{k(\theta + D_j)}{2c} - q_{1j}; \quad \text{and} \quad \Pi_2^*(q_{1j}) = D_j \left[\frac{k^2(\theta + D_j)^2}{4c} - k(\theta + D_j)q_{1j} + cq_{1j}^2 \right]. \quad (A2)$$

Thus, the maximization problem in period 1, with respect to q_{1j} , is

$$\max_{q_{1j}} \Pi_{Total}^j(q_{1j}) \equiv \Pi_1^j(q_{1j}) + \Pi_2^*(q_{1j}) \equiv D_j \left[(\theta + D_j)q_{1j} + \frac{k^2(\theta + D_j)^2}{4c} \right]. \quad (A3)$$

$$\Leftrightarrow \frac{\partial \Pi_{Total}^j}{\partial q_{1j}} \equiv D_j(\theta + D_j) > 0. \quad (A4)$$

\Leftrightarrow The optimal strategy for firm j is to introduce the total quality in period 1 subject to the constraint (A2) that the total quality $q_{1j} + q_{2j} = k(\theta + D_j)/2c$. Thus, the optimal strategy and profit of firm j is

$$q_{1j}^{CI} = \frac{k(\theta + D_j)}{2c}; \quad p_{1j}^{CI} = \frac{k(1+k)(\theta + D_j)^2}{2c}; \quad q_{2j}^{CI} = 0; \quad p_{2j}^{CI} = 0; \quad \Pi_{Total}^{CI} = \frac{D_j k(2+k)(\theta + D_j)^2}{4c}. \quad (A5)$$

■

Proof of Proposition 2:

From equation (A3), the total profit of H -type, as a function of q_{1H} , is

$$\Pi_{Total}^{H,H}(q_{1H}) = D_H \left[(\theta + D_H)q_{1H} + \frac{k^2(\theta + D_H)^2}{4c} \right]. \quad (A6)$$

But, by equation (A14), the total profit of L -type under mimicking, $\Pi_{Total}^{L,H}(q_{1H})$, as a function of q_{1H} , is

$$\Pi_{Total}^{L,H}(q_{1H}) = D_L \left[[\theta + D_H + k(D_H - D_L)]q_{1H} + \frac{k^2(\theta + D_L)^2}{4c} \right]. \quad (A7)$$

$$\Leftrightarrow \frac{\partial \Pi_{Total}^{H,H}(q_{1H})}{\partial q_{1H}} = D_H(\theta + D_H) < \frac{\partial \Pi_{Total}^{L,H}(q_{1H})}{\partial q_{1H}} = D_L[\theta + D_H + k(D_H - D_L)], \quad (A8)$$

when $k > \frac{\theta + D_H}{D_L} > 1$, which gives the condition for existence of a separating equilibrium.

■

Proof of Proposition 3:

Let q_{1H} be the first-period offered by the H -type firm in a separating equilibrium. First, consider the mimicking constraint of the L -type firm. The L -type firm has two options:

(i) *Not to mimic the H -type's strategy:* In this case, the L -type's true externality gets revealed in period 1 itself and it earns its complete-information profit, $\Pi_{Total}^{L,L}^*$, (c.f. equation A5)

$$\Pi_{Total}^{L,L}^* = \frac{D_L k(2+k)(\theta + D_L)^2}{4c}. \quad (A9)$$

(ii) *To mimic the H -type's strategy:* In this case, the L -type offers q_{1H} in period 1 and, under the most favorable consumer belief, is misperceived to be the H -type firm and therefore its first-period profit under mimicking, $\Pi_1^{L,H}(q_{1H})$, is

$$\Pi_1^{L,H}(q_{1H}) = D_L \left[(1+k)(\theta + D_H)q_{1H} - cq_{1H}^2 \right]. \quad (A10)$$

However, in period 2, its true type gets revealed. As such, the IR constraint for upgrade q_{2L} is

$$k(\theta + D_L)q_{2L} - p_{2L} \geq 0. \quad (A11)$$

$$\Rightarrow \Pi_2^{L,L} = D_L \left[k(\theta + D_L)q_{2L} - cq_{2L}^2 - 2cq_{1H}q_{2L} \right]. \quad (A12)$$

$$\Rightarrow q_{2L}^* = \frac{k(\theta + D_L)}{2c} - q_{1H}. \quad (A13)$$

\Rightarrow The L -type's total profits under mimicking, as a function of q_{1H} , is

$$\begin{aligned} \Pi_{Total}^{L,H}(q_{1H}) &\equiv \Pi_1^{L,H}(q_{1H}) + \Pi_2^{L,L}(q_{2L}^* | q_{1H}) \\ &\Rightarrow = D_L \left[[\theta + D_H + k(D_H - D_L)]q_{1H} + \frac{k^2(\theta + D_L)^2}{4c} \right]. \end{aligned} \quad (A14)$$

\Rightarrow The mimicking constraint (P2.6) in the H -type's optimization program P2 is given by

$$\begin{aligned} &\Rightarrow [\theta + D_H + k(D_H - D_L)]q_{1H} + \frac{k^2(\theta + D_L)^2}{4c} \leq \frac{k(2+k)(\theta + D_L)^2}{4c}, \\ &\Rightarrow q_{1H} \leq \frac{k(\theta + D_L)}{2c} \times \frac{\theta + D_L}{\theta + D_H + k(D_H - D_L)}. \end{aligned} \quad (A15)$$

But as shown in equation (A4), the H -type's total profit is increasing in q_{1H} . Therefore, in the least-cost separating equilibrium,

$$\bar{q}_{1H}^{SE} = \frac{k(\theta + D_L)}{2c} \times \frac{\theta + D_L}{\theta + D_H + k(D_H - D_L)} < q_{1L}^{CI} < q_{1H}^{CI}, \quad (A16)$$

and, by equation (A2),

$$\bar{q}_{2H}^{SE} = \frac{k(D_H - D_L)[(1+k)(\theta + D_H) + \theta + D_L]}{2c[\theta + D_H + k(D_H - D_L)]}, \quad (A17)$$

$$\Rightarrow \bar{q}_{Total}^H^{SE} = \bar{q}_{1H}^{SE} + \bar{q}_{2H}^{SE} = \frac{k(\theta + D_H)}{2c} = q_{1H}^{CI} + q_{2H}^{CI} = q_{Total}^H^{CI}. \quad (A18)$$

The signaling distortion in the H -type's first-period quality, as a fraction of the H -type's complete information price is given by

$$\frac{\Delta q_{1H}}{q_{1H}^{CI}} = \frac{q_{1H}^{CI} - \bar{q}_{1H}^{SE}}{q_{1H}^{CI}} = \frac{\bar{q}_{2H}^{SE}}{q_{1H}^{CI}} = \frac{(D_H - D_L)[(1+k)(\theta + D_H) + \theta + D_L]}{(\theta + D_H)^2 + k(D_H - D_L)(\theta + D_H)}, \quad (A19)$$

$$\Rightarrow \frac{\partial \left[\Delta q_{1H} / q_{1H}^{CI} \right]}{\partial k} = \frac{(D_H - D_L)(\theta + D_H)(\theta + D_L)^2}{\left[(\theta + D_H)^2 + k(D_H - D_L)(\theta + D_H) \right]^2} > 0. \quad (A20)$$

Thus, the fraction of quality withheld by the H -type firm to period 2 (necessary to achieve separation) increases as $k \geq 1$ increases. ■

Proof of Proposition 4:

Since the total quality provided under signaling is the same as that under complete information, the cost of signaling to the H -type results from the loss in revenue due to the firm's inability to charge first-period consumption benefit for the upgrade, \bar{q}_{2H}^{SE} , i.e.,

$$\begin{aligned} \Delta \Pi_{H,Total}^{Signaling} &\equiv \Pi_{Total}^H^{CI} - \Pi_{Total}^H^{SE} = (\theta + D_H) \times \Delta \bar{q}_{2H}^{SE} \\ &= \frac{k D_H (D_H - D_L)(\theta + D_H)[(1+k)(\theta + D_H) + \theta + D_L]}{2c[\theta + D_H + k(D_H - D_L)]}. \end{aligned} \quad (A21)$$

Thus, the loss in H -type's profit due to signaling, as a fraction of the H -type's complete information profit is given by

$$SC_H^{SE} \equiv \frac{\Delta \Pi_{H,Total}^{Signaling}}{\Pi_{Total}^{CI}} = \frac{2(D_H - D_L)(1+k)(\theta + D_H) + \theta + D_L}{(2+k)(\theta + D_H)(\theta + D_H + k(D_H - D_L))}, \quad (A22)$$

$$\Leftrightarrow \frac{\partial SC_H^{SE}}{\partial k} = \frac{-2(1+k)(D_H - D_L)^2(\theta + D_H)\{(1+k)(\theta + D_H) - 2(\theta + D_L)\}}{[(2+k)(\theta + D_H)(\theta + D_H + k(D_H - D_L))]^2} < 0. \quad (A23)$$

since $k \geq 1$ and $D_H > D_L$. Thus, the signaling cost borne by the H -type to achieve credible separation decreases as $k \geq 1$ increases. ■

Proof of Proposition 5:

First, consider firm j 's second-period problem of choosing the qualities of the upgrades, if any, given qualities of the base versions. Under the assumption that if a consumer buys base version q_{1E}^j in period 1, he can only buy upgrade q_{2E}^j in period 2, if at all, (the same holds for version q_{1N}^j), the second-period IR constraints (P3.3) and (P3.5) are binding and so we have

$$q_{2E}^{j*}, q_{2N}^{j*} \in \arg \max_{q_{2E}^j, q_{2N}^j} D_j \left[r_E \left\{ k(\theta_E + D_j) q_{2E}^j - c q_{2E}^{j2} - c q_{1E}^j q_{2E}^j \right\} + r_N \left\{ k(\theta_N + D_j) q_{2N}^j - c q_{2N}^{j2} - c q_{1N}^j q_{2N}^j \right\}, \quad (A24)$$

$$\Leftrightarrow q_{2E}^{j*} = \frac{k(\theta_E + D_j)}{2c} q_{1E}^j; \text{ and } q_{2N}^{j*} = \frac{k(\theta_N + D_j)}{2c} q_{1N}^j. \quad (A25)$$

Now, consider the firm's choice of first-period qualities of the base versions so as to maximize its total profit. Given that the second-period IR constraints are binding, the first-period IR and IC constraints (P3.2), (P3.4) and (P3.6) reduce to

$$(1+k)(\theta_E + D_j) q_{1E}^j - p_{1E}^j \geq 0, \quad (A26)$$

$$(1+k)(\theta_N + D_j) q_{1N}^j - p_{1N}^j \geq 0, \quad (A27)$$

$$(1+k)(\theta_E + D_j) q_{1E}^j - p_{1E}^j \geq (1+k)(\theta_E + D_j) q_{1N}^j + k(\theta_E + D_j) q_{2N}^{j*} - p_{1N}^j - p_{2N}^{j*}. \quad (A28)$$

In equilibrium, constraints (A27) and (A28) are binding while (A26) is slack. After some algebraic manipulation, the total profit of firm j as a function of first-period qualities (q_{1E}^j, q_{1N}^j) is given by

$$\Pi_{Total}^j = D_j \left[r_E \left\{ (\theta_E + D_j) q_{1E}^j - (\theta_E - \theta_N) \left[q_{1N}^j + \frac{k^2(\theta_N + D_j)}{2c} \right] + \frac{k^2(\theta_E + D_j)^2}{4c} \right\} + r_N \left\{ (\theta_N + D_j) q_{1N}^j + \frac{k^2(\theta_N + D_j)^2}{4c} \right\} \right]. \quad (A29)$$

$$\Leftrightarrow \frac{\partial \Pi_{Total}^j}{\partial q_{1E}^j} = D_j r_E (\theta_E + D_j) > 0, \text{ and} \quad (A30)$$

$$\begin{aligned} \frac{\partial \Pi_{Total}^j}{\partial q_{1N}^j} &= D_j \left[-r_E (\theta_E - \theta_N) + r_N (\theta_N + D_j) \right] \\ &= D_j [\theta_N - r_E \theta_E + r_N D_j] = D_j [\theta_N + D_j - r_E (\theta_E + D_j)] \quad (\because r_E + r_N = 1). \end{aligned} \quad (A31)$$

\Leftrightarrow Firm j provides all the quality to the experts in period 1 itself, i.e.,

$$q_{1E}^{jCI} = \frac{k(\theta_E + D_j)}{2c}; \text{ and } q_{2E}^{jCI} = 0. \quad (A32)$$

If $r_E < \frac{\theta_N + D_j}{\theta_E + D_j} < 1$, $\frac{\partial \Pi_{total}^j}{\partial q_{1N}^j} > 0$, and in this case, the total quality to the novices is introduced in period

1 itself, i.e.,

$$q_{1N}^{j, CI} = \frac{k(\theta_N + D_j)}{2c}; \text{ and } q_{2N}^{j, CI} = 0. \quad (A33)$$

In other words, when $r_E < \frac{\theta_N + D_j}{\theta_E + D_j} < 1$, *simultaneous introduction* strategy is optimal and dominates *sequential introduction* strategy wherein the firm postpones serving novices to the second period.

Substituting values of $q_{1E}^{j, CI}$ and $q_{1N}^{j, CI}$ in equation (A29), firm j 's optimal profit under complete information is given by

$$\Pi_{total}^{j, CI} = D_j \left[\frac{k(2+k)(\theta_N + D_j)^2}{4c} + r_E \frac{k(\theta_E - \theta_N) \{2(\theta_E + D_j) + k(\theta_E - \theta_N)\}}{4c} \right]. \quad (A34)$$

When $1 > r_E > \frac{\theta_N + D_j}{\theta_E + D_j}$, $\frac{\partial \Pi_{total}^j}{\partial q_{1N}^j} < 0$ and so firm j does not introduce any version for novices in period 1, i.e., $q_{1N}^{j, CI} = \varepsilon = 0$ where ε is arbitrarily small. Regarding period 2, firm j has two options:

- (a) Not to serve novices at all, i.e., $q_{2N}^{j, CI} = 0$; this is still a simultaneous introduction strategy with partial market coverage; or,
- (b) Introduce $q_{2N}^{j, CI} = k(\theta_N + D_j)/2c$ (using equation A25); this is the sequential introduction strategy.

The following lemma establishes that when $1 > r_E > \frac{\theta_N + D_j}{\theta_E + D_j}$, sequential introduction is not optimal.

Lemma 1: When $1 > r_E > \frac{\theta_N + D_j}{\theta_E + D_j}$, *sequential introduction strategy is not optimal.*

Proof of Lemma 1: Assume to the contrary that sequential introduction is optimal. Now, the IC constraint (A28) implies that an expert consumer enjoys a surplus of

$$CS_E \equiv (1+k)(\theta_E + D_j)q_{1E}^j - p_{1E}^j = k(\theta_E + D_j)q_{2N}^j - p_{2N}^j = k(\theta_E - \theta_N)q_{2N}^j,$$

since second-period IR for q_{2N}^j will be binding. Thus, the total surplus left with the experts is

$$\text{Surplus left with Experts} = D_j r_E \frac{k^2(\theta_E - \theta_N)(\theta_N + D_j)}{2c}, \quad (A35)$$

while the profits earned from the novice segment is

$$\Pi_{2N}^j = D_j r_N \{k(\theta_N + D_j)q_{2N}^j - cq_{2N}^{j, 2}\} = D_j r_N \frac{k^2(\theta_N + D_j)^2}{4c}. \quad (A36)$$

But since sequential introduction is optimal

$$\begin{aligned} \Leftrightarrow D_j r_N \frac{k^2(\theta_N + D_j)^2}{4c} &> D_j r_E \frac{k^2(\theta_E - \theta_N)(\theta_N + D_j)}{2c}, \\ \Leftrightarrow \frac{\theta_N + D_j}{2\theta_E + D_j} &> r_E. \end{aligned} \quad (A37)$$

But this violates the condition $r_E > \frac{\theta_N + D_j}{\theta_E + D_j}$ as $\frac{\theta_N + D_j}{\theta_E + D_j} > \frac{\theta_N + D_j}{2\theta_E + D_j}$. Thus, sequential introduction is not optimal and the firm's optimal strategy is not to serve the novices. ■

Proof of Proposition 6:

From equation (A29), the total profit of the H -type as a function of q_{1E}^H and q_{1N}^H is

$$\begin{aligned} \Pi_{Total}^{H,H}(q_{1E}^H, q_{1N}^H) = & D_H \left[r_E \left\{ (\theta_E + D_H) q_{1E}^H - (\theta_E - \theta_N) \left[q_{1N}^H + \frac{k^2(\theta_N + D_H)}{2c} \right] + \frac{k^2(\theta_E + D_H)^2}{4c} \right\} \right. \\ & \left. + r_N \left\{ (\theta_N + D_H) q_{1N}^H + \frac{k^2(\theta_N + D_H)^2}{4c} \right\} \right]. \end{aligned} \quad (A38)$$

$$\Leftrightarrow \frac{\partial \Pi_{Total}^{H,H}}{\partial q_{1E}^H} = D_H r_E (\theta_E + D_H) \quad \text{and} \quad \frac{\partial \Pi_{Total}^{H,H}}{\partial q_{1N}^H} = D_H [\theta_N - r_E \theta_E + r_N D_H]. \quad (A39)$$

However, by equation (A47), the total profit of the L -type under mimicking, as a function of q_{1E}^H and q_{1N}^H is

$$\begin{aligned} \Pi_{Total}^{L,H}(q_{1E}^H, q_{1N}^H) = & D_L \left[r_E \left\{ [(\theta_E + D_H) + k(D_H - D_L)] q_{1E}^H - (\theta_E - \theta_N) \left[q_{1N}^H + \frac{k^2(\theta_N + D_H)}{2c} \right] + \frac{k^2(\theta_E + D_L)^2}{4c} \right\} \right. \\ & \left. + r_N \left\{ [(\theta_N + D_H) + k(D_H - D_L)] q_{1N}^H + \frac{k^2(\theta_N + D_L)^2}{4c} \right\} \right]. \end{aligned} \quad (A40)$$

$$\Leftrightarrow \frac{\partial \Pi_{Total}^{L,H}}{\partial q_{1E}^H} = D_L r_E [\theta_E + D_H + k(D_H - D_L)]; \quad \frac{\partial \Pi_{Total}^{L,H}}{\partial q_{1N}^H} = D_L [\theta_N - r_E \theta_E + r_N D_H + r_N k(D_H - D_L)]. \quad (A41)$$

$$\begin{aligned} \Leftrightarrow \frac{\partial \Pi_{Total}^{L,H}}{\partial q_{1E}^H} > \frac{\partial \Pi_{Total}^{H,H}}{\partial q_{1E}^H} \quad \text{when} \quad k > (\theta_E + D_H) / D_L > 1 \quad \text{and} \quad \frac{\partial \Pi_{Total}^{L,H}}{\partial q_{1N}^H} > \frac{\partial \Pi_{Total}^{H,H}}{\partial q_{1N}^H} \quad \text{when} \\ k > \frac{\theta_E + D_H}{D_L} > \frac{\theta_N - r_E \theta_E + r_N D_H}{r_N D_L}, \end{aligned} \quad (A42)$$

which gives the necessary condition for existence of a separating equilibrium. Further, under this parametric condition

$$\begin{aligned} \frac{\partial \Pi_{Total}^{L,H}}{\partial q_{1N}^H} / \frac{\partial \Pi_{Total}^{H,H}}{\partial q_{1N}^H} > \frac{\partial \Pi_{Total}^{L,H}}{\partial q_{1E}^H} / \frac{\partial \Pi_{Total}^{H,H}}{\partial q_{1E}^H} > 1, \quad (A43) \\ \Leftrightarrow \frac{D_L [\theta_N - r_E \theta_E + r_N D_H + r_N k(D_H - D_L)]}{D_H [\theta_N - r_E \theta_E + r_N D_H]} > \frac{D_L [\theta_E + D_H + r_N k(D_H - D_L)]}{D_H (\theta_E + D_H)}, \\ \Leftrightarrow \theta_E > \theta_N. \end{aligned}$$

Proof of Proposition 7:

Let q_{1E}^H and q_{1N}^H be the first-period qualities, targeted at the experts and novices respectively, offered by the H -type firm in a separating equilibrium. If the L -type were not to mimic the H -type but instead follow its complete information strategy (simultaneous introduction characterized in Proposition 5), then the L -type earns a profit (c.f. equation A34)

$$\Pi_{Total}^{L,L} = D_L \left[\frac{k(2+k)(\theta_N + D_L)^2}{4c} + r_E \frac{k(\theta_E - \theta_N) \{2(\theta_E + D_L) + k(\theta_E - \theta_N)\}}{4c} \right]. \quad (A44)$$

If, on the other hand, the L -type mimics the H -type's strategy, then it offers q_{1E}^H and q_{1N}^H in period 1 and, under the most favorable consumer belief, is misperceived to be the H -type firm. Therefore, its first-period profit under mimicking, $\Pi_1^{L,H}(q_{1E}^H, q_{1N}^H)$, is

$$\Pi_1^{L,H} = D_L \left[r_E \left\{ (1+k)(\theta_E + D_H) q_{1E}^H - (\theta_E - \theta_N) \left[q_{1N}^H + \frac{k^2(\theta_E + D_H)}{2c} \right] - c q_{1E}^H \right\} \right] \quad (A45)$$

$$+ r_N \left\{ (1+k)(\theta_N + D_H) q_{1E}^H - c q_{1N}^H \right\}^2 \Big].$$

However, in period 2, its true externality-type gets revealed and hence, by equation (A25), the optimal second-period qualities of the L -type firm, given that it mimicked the first-period qualities (q_{1E}^H, q_{1N}^H) of the H -type firm in the first period are given by

$$q_{2E}^{L*} = \frac{k(\theta_E + D_L)}{2c} - q_{1E}^H; \text{ and } q_{2N}^{L*} = \frac{k(\theta_N + D_L)}{2c} - q_{1N}^H, \quad (\text{A46})$$

and thus the L -type's total profits under mimicking, $\Pi_{Total}^{L,H}$, as a function of is q_{1E}^H and q_{1N}^H , is

$$\begin{aligned} \Pi_{Total}^{L,H} &= \Pi_1^{L,H}(q_{1E}^H, q_{1N}^H) + \Pi_2^{L,L}(q_{2E}^{L*}, q_{2N}^{L*} | q_{1E}^H, q_{1N}^H) \\ &= D_L \left[r_E \left\{ [(\theta_E + D_H) + k(D_H - D_L)] q_{1E}^H - (\theta_E - \theta_N) \left[q_{1N}^H + \frac{k^2(\theta_N + D_H)}{2c} \right] + \frac{k^2(\theta_E + D_L)^2}{4c} \right\} \right. \\ &\quad \left. + r_N \left\{ [(\theta_N + D_H) + k(D_H - D_L)] q_{1N}^H + \frac{k^2(\theta_N + D_L)^2}{4c} \right\} \right]. \end{aligned} \quad (\text{A47})$$

Therefore, the mimicking constraint $\Pi_{Total}^{L,H} \leq \Pi_{Total}^{L,L*}$ is given by

$$\begin{aligned} r_E \left\{ [(\theta_E + D_H) + k(D_H - D_L)] q_{1E}^H - (\theta_E - \theta_N) \left[q_{1N}^H + \frac{k^2(\theta_N + D_H)}{2c} \right] + \frac{k^2(\theta_E + D_L)^2}{4c} \right\} + r_N \left\{ \frac{k^2(\theta_N + D_L)^2}{4c} \right\} \\ + r_N \left\{ [(\theta_N + D_H) + k(D_H - D_L)] q_{1N}^H \right\} \leq \frac{k(2+k)(\theta_N + D_L)^2}{4c} + r_E \frac{k(\theta_E - \theta_N) \{ 2(\theta_E + D_L) + k(\theta_E - \theta_N) \}}{4c}. \end{aligned} \quad (\text{A48})$$

To deter mimicking, the H -type can either decrease q_{1E}^H or q_{1N}^H in (A48). However, by equation (A43), q_{1N}^H is a superior signaling mechanism in the sense that the H -type's marginal ability to separate is higher on q_{1N}^H than on q_{1E}^H . Therefore, the H -type distorts q_{1N}^H completely to 0 before distorting q_{1E}^H , i.e.,

$$\bar{q}_{1N}^{H SE} = \varepsilon = 0, \quad (\text{A49})$$

where ε is arbitrarily small. Thus, the mimicking constraint (A48) reduces to

$$\begin{aligned} r_E \left\{ [(\theta_E + D_H) + k(D_H - D_L)] q_{1E}^H \right\} \leq \frac{r_E k^2 (\theta_E + D_H) (\theta_E - \theta_N)}{2c} \\ - \frac{k \left\{ r_E (\theta_E - \theta_N) [k(\theta_N + D_L) - (\theta_E + D_L)] - (\theta_N + D_L)^2 \right\}}{2c}, \end{aligned} \quad (\text{A50})$$

and since the H -type's total profit is increasing in q_{1E}^H (by equation A30), the separating equilibrium quality offered to the experts in the first period is given by

$$\bar{q}_{1E}^{H SE} = \frac{k(\theta_E + D_H)}{2c} \times \frac{k(\theta_E - \theta_N)}{\theta_E + D_H + k(D_H - D_L)} - \frac{k \left\{ r_E (\theta_E - \theta_N) [k(\theta_N + D_L) - (\theta_E + D_L)] - (\theta_N + D_L)^2 \right\}}{2c r_E [\theta_E + D_H + k(D_H - D_L)]}, \quad (\text{A51})$$

while the optimal second-period qualities of the upgrade $\bar{q}_{2E}^{H SE}$ (targeted at the experts) and the new release

$\bar{q}_{2E}^{H SE}$ targeted at the novices (by equations (A25), (A51) and (A49)) are given by

$$\bar{q}_{2E}^{H SE} = \frac{k(\theta_E + D_H)}{2c} - \bar{q}_{1E}^{H SE}; \text{ and } \bar{q}_{2N}^{H SE} = \frac{k(\theta_N + D_H)}{2c}. \quad (\text{A52})$$

In contrast, the L -type follows its complete-information strategy given by equations (A32) and (A33). ■