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Efficient Upgrading in Durable Network Goods: Is Commitment Always Good?

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Abstract

In this article I explore an incumbent monopolist's incentives to upgrade in the future his durable network product in the presence of overlapping generations of customers and a potential entrant who may also sell a version of the same quality. When the incumbent has commitment power and entry cannot be deterred, he decides to withhold the upgrade when network effects are weak, as strategic complementarity between the competitors' intertemporal pricing decisions allows him to charge sufficiently patient forward-looking consumers more in the present market. On the other hand, he commits to upgrade when network effects are strong, as there is strategic substitutability between firms' prices. Regarding welfare, the frequency of new products is not socially optimal when the quality improvement is negligible and smaller than their adoption cost. I find that both potential or actual competition and the incumbent's commitment power are sources of inefficiency.

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1 Introduction

Is an incumbent monopolist always better-off by currently committing to upgrade in the future his durable network product in the presence of a competitor who may potentially sell a product of the same quality? What is the role of consumers in the incumbent's upgrade decision? Is potential or actual competition socially efficient in a dynamic setting with technological advancements and overlapping generations of consumers? Is the incumbent's power to commit socially welcome, or unlike monopolies, it may create further inefficiencies?

This article aims to give some answers to these questions. More specifically, I explore a market leader's incentives to provide an upgrade of his software in the presence of overlapping generations of forward-looking consumers and a competitor who could potentially offer a good of the same quality. Consumers incur both the monetary cost and a cost of learning how to use any product and it is the latter cost that determines whether introducing the new product into the market is socially optimal: society would be better off without it if the social benefit from the quality improvement from its introduction is lower than the social cost.

Our results recognize potential or actual competition as well as the incumbent's commitment power as sources of inefficiency. More precisely, although the introduction of the new product may not be socially efficient, the market leader always commits to upgrade when this choice deters the competitor from investing. If the rival's entry is certain, the incumbent commits not to upgrade for most parameter values because such a choice enables him to charge sufficiently patient customers more in the present market. In particular, firms' intertemporal price choices become strategic complements and the incumbent firm can set a higher price today if it allows the rival to be the sole supplier of an improved product in the future. When network effects are strong, the incumbent is better-off by committing to upgrade, as in this case, firms' prices become strategic substitutes. Furthermore, if the rival cannot price discriminate between the old and the new users, although the new version is an important improvement, the incumbent's commitment may lead the old consumers to stick to the old product, while social efficiency is obtained when he lacks commitment power. Thus, forbidding the incumbent to commit may in fact raise social welfare.

1.1 Related literature

This article links to the literature on durable goods by examining how durability affects the pricing and innovation behaviour of an incumbent firm and a potential competitor. It also relates to the discussion regarding whether a durable goods monopolist implements the socially optimal level of technological progress when he faces potential or actual competition. Waldman (1993, 1996) as well as Fudenberg and Tirole (1998) and Choi (1994) examined whether the time inconsistency problem faced by a durable goods monopolist might be overcome if the firm introduces a new product. Although these papers recognized the linkage between the present and future market on the monopolist's pricing and investment decisions, they do not allow for potential or actual competition. Hoppe and Lee (2003) show that the intertempolar linkage may introduce inefficiency in investment if there is a potential entrant that may also innovate. Unlike Bucovetsky and Chilton (1986) and Bulow (1986), Hoppe and Lee (2003) consider a competitor who can come up with a new generation of the good currently supplied by the incumbent monopolist. They identify limit pricing as a source of inefficiency, and they also shed light on Microsoft's puzzling pricing strategy in Operating systems as a virtual monopolist would charge much more than the technology giant. Fudenberg and Tirole (2000) show that an incumbent monopolist may use limit pricing for his network good to deter entry of a potential entrant's incompatible product. Our work differs because, unlike Fudenberg and Tirole (2000), we consider durability coupled with network externalities, allowing for compatibility between the competitors' products. Meanwhile, contrary to Hoppe and Lee (2003) and Fudenberg and Tirole (2000), we no longer identify limit pricing but rather, potential or actual competition as a source of inefficieny. Ellison and Fudenberg (2000) is the paper that is closest to this work. The authors consider a durable goods monopolist's incentives to offer an upgrade of his product in the future period. If consumers are homogeneous, the lack of the firm's commitment power is a source of potential inefficiency because the monopolist always sells the new version in the second period even if its improvement is negligible and thus, not profitable overall. So, his inability to commit may hurt his profits as well as social welfare. Unlike Ellison and Fudenberg (2000) where commitment is socially desirable, I find that this is no longer true in a scenario when competition is present.

2 The model

2.1 Supply

Consider an industry where a software, durable product of quality q_1 is currently supplied by a market leader.[3] He is considering whether to upgrade his product in the next period by selling a good of superior quality $q_2 > q_1$. The choice of upgrading does not involve any cost of development as previous investment provides the incumbent with the technology to launch the new product. The incumbent knows that there is a serious threat of a rival firm that can also develop a good of the same quality q_2.[4]

At date t=1, the incumbent sets the price for his product of quality q_1 and if he has commitment power, he also has an additional simultaneous choice to make: whether to commit to upgrade at date t=2 or not. At the same time, the competitor needs to decide whether she will enter the market in the following period.

At date t=2, if entry occurs, the two firms engage in price competition (a la Bertrand). Although the incumbent can exercise price discrimination between the old and new date t=2 customers, I investigate both the cases where the rival can price discriminate between the different consumers' classes and when she cannot. Both firms incur a zero marginal

[3] We follow Ellison and Fudenberg who also consider quality as a positive, real number q.

[4] She will be called rival, competitor or entrant interchangeably throughout the paper.

cost of production for all product versions[5] and when their net benefit from following any of two possible choices is equivalent, they make a decision that lowers the opponent's expected profits.

The model makes the strong assumption that the competitors' superior quality products are compatible. Thus, a buyer of a high quality good can interact with all the superior product buyers, independently of whether they purchase it from the incumbent or the entrant firm. Backward compatibility allows the buyers of any new product to open and save a document that was created with the lower quality product. On the other hand, forward incompatibility prevents the buyers of the initial product from working with documents that are created with the superior version.[6]

2.2 Demand

Consumers are identical and arrive in constant flows of measure λ_t $(t = 1, 2)$. Their utility is linear in income and is positively dependent on network effects captured by the parameter α. Thus, if the buyer joins a network of mass x (including himself), the network benefit is αx. In addition to the monetary cost, consumers also incur a cost of learning the new technology. Each consumer incurs a cost c the first time he starts to use the incumbent monopolist's product, which is followed by an additional lower cost $(c_u < c)$ when learning to use a new product.

Customers of measure λ_1, who arrive in the market at date t=1, are forward-looking and, depending on their expectations, they may either buy the initial good immediately after observing its price or postpone their decision to the future. Their expectations reflect the information available to consumers at the time they are called to make their buying decision and are fully aligned in equilibrium; that is, they possess perfect foresight.

At date t=2 and if there is a new product of quality q_2 in the market, customers of measure

[5] This assumption is consistent with the applications in the computer software market industry.

[6] See Ellison and Fudenberg (2000) for a paper where backward compatibility and forward incompatibility are also present.

λ_1 may not buy it because of the durability of the version of quality q_1. These customers' purchasing decision given announced prices resembles a coordination game and can have multiple equilibria. Following the literature, old consumers coordinate to the Pareto optimal outcome.[7] In the similar coordination problem related to new date t=2 customers' of measure λ_2 purchasing decisions, the standard assumption is that buyers with the same preferences act as if they were a single player. Thus, after observing the prices, they coordinate to what is best for all of them. All consumers make their purchasing decisions simultaneously where we assume that they prefer a better than an inferior product even if their net utility is equivalent. Also note that the same discount factor δ applies to all the agents in the economy.

3 Results

3.1 Social Welfare

I begin by considering the problem faced by a planner who maximises social surplus and must decide whether it is socially beneficial if the new product of quality q_2 is introduced or the old version is used for both periods.[8] In the former case, it may be efficient if the new product is used either by all or only by the new date t=2 potential customers.

If all date t=2 customers use the new product, social welfare is:

$$W_U = \lambda_1(q_1 + \delta q_2 + \alpha\lambda_1 + \delta\alpha - c - \delta c_u) + \lambda_2\delta(q_2 + \alpha - c),$$

where without loss of generality, the market size in the second period is normalized to unity. If the new product is introduced and only the new date t=2 customers use it, social welfare is:

$$W_I = \lambda_1[(1+\delta)q_1 + (1+\delta)\alpha\lambda_1 - c] + \lambda_2\delta(q_2 + \alpha - c).$$

[7] See Ellison and Fudenberg (2000).

[8] This discussion follows Ellison and Fudenberg (2000).

Note that because of forward incompatibility of the old product of quality q_1, the measure λ_1 of old date t=2 consumers join a network of size λ_1 at date t=2. Moreover, backward compatibility of the product of quality q_2 allows the measure λ_2 of new date t=2 consumers to join a network of maximum size. If the lower quality product is used for both periods, social welfare is given by the expression:

$$W_N = \lambda_1[(1+\delta)q_1 + \alpha\lambda_1 + \delta\alpha - c] + \lambda_2\delta(q_1 + \alpha - c).$$

Comparing the above expressions yields the next proposition that summarizes the socially efficient outcome.

Proposition 1 *Let $\Delta q = q_2 - q_1$ denote the quality improvement from the introduction of the new product. The socially efficient outcome is (a) keep the lower quality good for two periods if $a > c_u$ and $\Delta q < \lambda_1 c_u$ or if $\alpha < c_u$ and $\Delta q < \alpha\lambda_1$, (b) use the incompatible regime, that is, introduce the new product but only the second period potential customers use it if $\Delta q > \alpha\lambda_1$ and $\Delta q + \alpha\lambda_2 < c_u$ and (c) introduce the new product and everyone uses it in the second period if $\alpha > c_u$ and $\Delta q > \lambda_1 c_u$ or if $\alpha < c_u$ and $\Delta q > c_u - \alpha\lambda_2$.*

Think of the case that the network effects are large relative to the old date t=2 users' adoption cost for the product of quality q_2 ($\alpha > c_u$). It is socially efficient to maintain the lower quality good if the cost of learning how to use the new product for the old users exceeds the gain in every customer's second period utility ($\Delta q < \lambda_1 c_u$) and it is socially efficient for everyone to purchase the new product if the sign of the previous inequality is reversed ($\Delta q > \lambda_1 c_u$). When network effects are weak ($\alpha < c_u$), it is socially optimal to withhold the superior product when the loss from incompatibility is greater than the benefit the new users enjoy from the new version ($\Delta q\lambda_2 < \alpha\lambda_1\lambda_2$). It is also socially efficient if everyone uses the new product when the quality improvement and the gains from a larger network are greater than the adoption cost ($\Delta q + \alpha\lambda_2 > c_u$), whereas it is socially optimal if only the new buyers use it when the last inequality is reversed. Figure 1 provides a graphical representation of the socially optimal outcome.

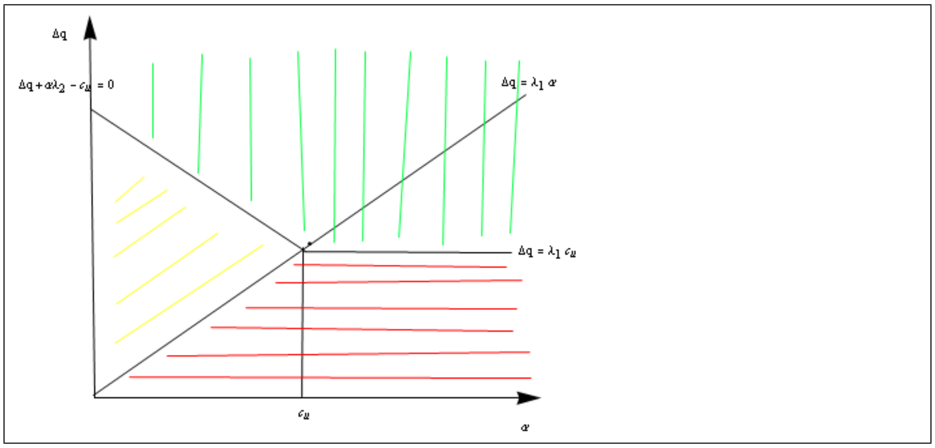

Figure 1: The socially optimal outcome: The red area indicates values in the parameter space where using the old product for two periods is socially optimal. The yellow area represents parameter values where it is socially efficient if only the new customers use the new product. The green area captures the case where it is socially optimal if everyone uses the superior good.

3.2 Market outcome/ Incumbent's commitment

I consider a scenario of potential entry when the incumbent has already acquired the technology allowing him to commit to choose to upgrade in the following period. I analyze first the case when entry is certain and the entrant may or may not have the ability to price discriminate between the old and the new customers.

3.2.1 Certain entry/ The rival can price discriminate[9]

If the incumbent commits to upgrade, at date t=2, Bertrand competition drives all the prices to zero.[10] If he currently commits not to upgrade, the date t=2 prices the rival can set to old and new consumers are strictly positive. Moreover, there are two opposing effects on the price the incumbent can charge to the measure λ_1 potential customers at date t=1. If the

[9] Certain entry can be generated when the investment cost relates to past R&D activity. Alternatively it could also be generated either when the associated investment cost is small or the rival's product has a lower adoption cost than the incumbent's upgrade. Here, we focus on the situation when the rival's and incumbent's new products incur the same adoption cost to potential consumers.

[10] A complete characterization of the prices set and the market outcome is given in the Appendix.

quality improvement is such that date t=1 customers get the product of quality q_2 at date t=2 ($\Delta q + \alpha\lambda_2 - c_u \geq 0$), both their net discounted payoff if they purchase q_1 and if they postpone their purchase are lower compared to the scenario when the incumbent commits to upgrade.[11] If the latter effect outweighs the former, the incumbent is currently better-off by committing not to upgrade. The next proposition summarizes the incumbent's choice and the equlibrium market outcome for the different parameter values.

Proposition 2 *The incumbent commits not to upgrade for all parameter values except for the case when $\Delta q+\alpha\lambda_2-c_u \geq 0$ and $\alpha\lambda_2 \geq c_u$. In the second period, either the whole market (if $\Delta q+\alpha\lambda_2-c_u \geq 0$) or only the new comers (if $\Delta q+\alpha\lambda_2-c_u < 0$) buy the superior rival's version of quality q_2.*

Thus, for most parameter values, the intertemporal price choices for the competitors become strategic complements for the incumbent firm and it can currently charge date t=1 consumers more if it commits not to upgrade. On the other hand, when network effects are strong ($\alpha\lambda_2 \geq c_u$ and $\Delta q + \alpha\lambda_2 - c_u \geq 0$), the rivals' prices are strategic substitutes and the incumbent monopolist is better-off by committing to upgrade in the future period.

The proposition above suggests that in equilibrium, the higher quality good is always sold at date t=2 and is purchased either by the whole market or only by the new customers. This fact already highlights the potential inefficiency that may arise in the market as it could be socially beneficial if the product of quality $q_1$is used for both periods. The next proposition summarizes the comparison between the market equilibrum and the socially optimal outcome:

Proposition 3 *It is socially optimal if there is no new product in the second period and nevertheless: (a) all date t=2 consumers buy the rival's product of quality q_2 if $\Delta q + \alpha\lambda_2 - c_u \geq 0$, $\Delta q < \lambda_1 c_u$ (these parameter values imply that $a \geq c_u$). (b) only the new potential customers purchase the rival's product if $\Delta q + \alpha\lambda_2 - c_u < 0$, $\Delta q < \alpha\lambda_1$(these parameter values imply that $\alpha < c_u$).*

[11] See the Appendix for the competitors' price choices when the incumbent commits not to upgrade.

Society would be better-off if the initial version was used for both periods when the network benefit is relatively large ($\alpha \geq c_u$) and the adoption cost for the old users exceeds the gain in every customer's second period utility from the quality improvement when they use the new product ($\Delta q < \lambda_1 c_u$). Nevertheless, the product of quality q_2 is always sold in the market and everyone buys it if the quality improvement and the gains from a larger network are greater than the costs of learning how to use it ($\Delta q + \alpha\lambda_2 - c_u \geq 0$). For relatively weak network benefits compared to the adoption cost for the product of quality q_2 ($\alpha < c_u$), it is socially efficient to withhold the high quality product if the loss from incompatibility is greater than the utility benefit the new users enjoy from the new version ($\Delta q\lambda_2 < \alpha\lambda_1\lambda_2$). However, the entrant sells the superior product and only the new potential customers purchase it when the cost of learning how to use it for the old users is higher than their benefit form upgrading ($\Delta q + \alpha\lambda_2 - c_u < 0$). Therefore, inefficiency may occur as a result of actual competition when the incumbent can commit to his future actions and figure 2 represents diagrammatically the potential inefficiency that may arise in the market.

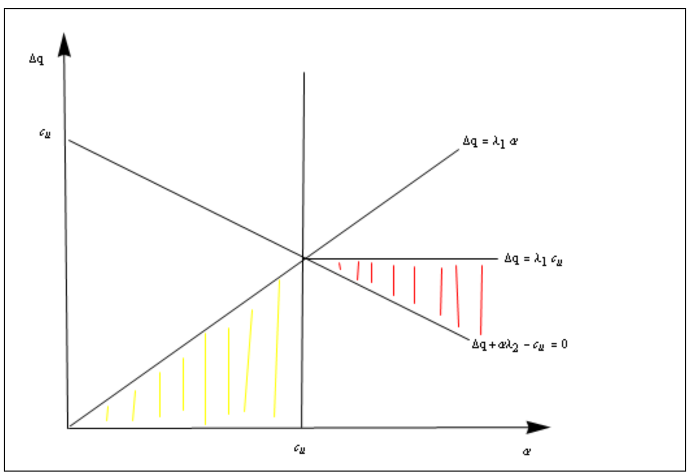

Figure 2: Market outcome and efficiency: The red and yellow shaped areas in the parameter space represent inefficient use of a new product by all consumers and only the new users, respectively.

3.2.2 Certain Entry/ The rival cannot price discriminate

If the entrant is unable to price discriminate, the analysis when the incumbent commits to upgrade leads to the same prices set by the competitors as in the case when the rival has the power to exercise price discimination.[12] If the incumbent monopolist commits not to upgrade, the entrant needs to decide whether to serve all the market in the second period or sell the superior product only to the new comers.[13] The next proposition summarizes the incumbent's choices as well as the market equilibrium outcome.

Proposition 4 *(a) If $\Delta q + \alpha\lambda_2 - c_u < 0$ or $\Delta q + \alpha\lambda_2 - c_u \geq 0$, $\Delta q\lambda_1 + \alpha\lambda_2 < c_u$, $\alpha\lambda_2 < c_u$, the incumbent commits not to upgrade and the entrant serves only the new comers. (b) If $\Delta q + \alpha\lambda_2 - c_u \geq 0$, $\Delta q\lambda_1 + \alpha\lambda_2 - c_u \geq 0$, $\alpha\lambda_2 < c_u$, the incumbent commits not to upgrade and the entrant serves the whole market. (c) If $\Delta q + \alpha\lambda_2 - c_u \geq 0$, $\alpha\lambda_2 > c_u$, the incumbent is indifferent between committing to upgrade or not.*

The proposition above suggests that in equilibrium and similar to the case that the entrant can exercise price discrimination, the higher quality good is always sold and is purchased either by the whole market or only by the new customers. Note that under most parameter values, the incumbent commits not to sell the higher quality good because if he sold the upgrade, actual competition would lower his total profits. The next proposition highlights the potential inefficiency that may arise in the market.

Proposition 5 *A) It is socially optimal if the initial product is used for both periods and nevertheless, (a) the higher quality product is sold to the whole market if $\Delta q + \alpha\lambda_2 - c_u \geq 0$, $\Delta q\lambda_1 + \alpha\lambda_2 - c_u \geq 0$, $\Delta q < \lambda_1 c_u$. (b) the entrant's higher quality good is sold only to the new customers if $\Delta q + \alpha\lambda_2 - c_u < 0$, $\Delta q < \alpha\lambda_1$ or if $\Delta q + \alpha\lambda_2 - c_u \geq 0$, $\Delta q\lambda_1 + \alpha\lambda_2 < c_u$, $\alpha\lambda_2 < c_u$ and $\Delta q < \lambda_1 c_u$. B) It is socially optimal for everyone to use the new product but the entrant sells the new product only to the new potential customers if $\Delta q + \alpha\lambda_2 - c_u \geq 0$, $\Delta q\lambda_1 + \alpha\lambda_2 < c_u$, $\alpha < c_u$.*

[12] See the appendix for the complete characterization of the equilibrium prices and market outcome.
[13] Again, the Appendix contains all the different cases.

Thus, there may be a superior product in the market even though society would be better-off without it for the same parameter values as in the case the entrant can price discriminate. There is also an additional inefficiency (B): when old second period customers' benefit from using the new product offsets their adoption cost and the first period market size is relatively small, the social optimum is achieved when everyone uses the new product and nevertheless, the entrant sells the superior good only to the new buyers. Figure 3 represents the potential inefficiency that may arise in the market.

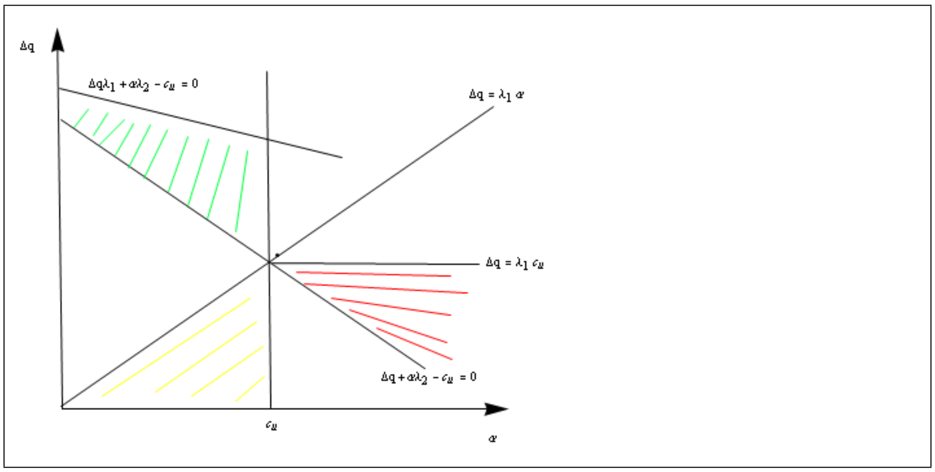

Figure 3: Market outcome and efficiency: The red and yellow shaped areas in the parameter space represent inefficient use of a new product. The green area represents the additional inefficiency when the new product is purchased only by the new comers while it is socially optimal for everyone to use a new version.

3.2.3 Potential entry

Consider now the case that entry can be deterred. If the incumbent commits to upgrade, the potential entrant is deterred to enter the market.[14] If the incumbent commits not to upgrade, the analysis is identical with the scenario of certain entry under the condition that the competitor's development cost is not prohibitively high.[15] The incumbent compares the profit gained by her commitment to either withhold the high quality good or sell it in the

[14] The post-entry game is analyzed in the appendix.

[15] See the appendix for the characterization of the equilibrium prices and profits.

second period and the next result summarizes his choice as well as the market outcome. Note that these results are independent of whether the entrant has the ability to price discriminate:

Proposition 6 *The incumbent monopolist always commits to sell the superior product in the second period and the potential entrant is deterred to enter. If a)* $\Delta q + \alpha\lambda_2 - c_u \geq 0$*, all the market purchases the upgrade, b)* $\Delta q + \alpha\lambda_2 - c_u < 0$*, only the new customers upgrade.*

The incumbent firm's choice to always commit to upgrade may be socially inefficient as it could be socially optimal if there was no upgrade in the market. This potential inefficiency is highlighted in the next result.

Proposition 7 *It is socially optimal for the low quality good to be sold in the market in both periods and nevertheless, (a) the incumbent commits to sell the upgrade and the whole market buys it when* $\Delta q + \alpha\lambda_2 - c_u \geq 0$ *and* $\Delta q < \lambda_1 c_u$*, (b) the incumbent commits to sell the superior good and only the new customers purchase it when* $\Delta q + \alpha\lambda_2 - c_u < 0$ *and* $\Delta q < \alpha\lambda_1$*.*

Note that inefficiency may arise for the same parameter values as in the case when the entrant's entry is certain and she can price discriminate between the old and the new users.

3.3 Market outcome/ No commitment for the incumbent

In this subsection, I will discuss the case when the incumbent firm faces the threat of entry and cannot commit to its future actions.

3.3.1 Certain Entry

When entry is certain, although the incumbent's revenue is zero at date t=2 independently of whether he upgrades or not, he will choose to sell the upgrade in the market, because otherwise, the entrant would enjoy positive profits. Therefore, there will be a product of quality q_2 in the second period sold by both competitors and this may be socially inefficient.

In particular, if the competitor has the power to price discriminate between the different consumer classes, the potential inefficiency arises for the same parameter values as in the case that the incumbent can commit (see proposition 3). An interesting result is that when the entrant lacks the power to price discriminate, the economy when the incumbent has the ability to commit may lead to additional inefficiency compared to the case when he lacks this ability: while it may be socially optimal for all customers to purchase the product of quality q_2, and unlike the scenario when the incumbent lacks the power to commit, old date t=2 customers may keep the initial version when the incumbent can commit (B in proposition 5). Therefore, contrary to the monopolistic environment where social optimality is achieved under the incumbent firm's commitment power, lack of commitment may raise social welfare when the market is open to competition.

3.3.2 Potential Entry

When entry can be detterred, the incumbent is the sole supplier of the upgrade at date t=2 and in anticipation of his behaviour, the competitor decides not to enter the market.[16] Thus, the range of inefficiency appears to be exactly the same as in the case when the incumbent can commit to his future actions (see proposition 3). To summarize, the inefficiency range when the incumbent firm enjoys or lacks commitment power and the fixed development cost for the entrant is strictly positive or zero, respectively, are highlighted in the following table:

[16] See the Appendix for a more formal argument regarding the post entry date t=2 game.

	Commitment for the incumbent	No commitment for the incumbent
Monopoly	Social efficiency	Inefficiency: The monopolist always upgrades even though it could be socially optimal if there is no upgrade in the market
Potential Competition (F>0)	Inefficiency: The same range as in the monopoly case under no commitment	Inefficiency: Same range as in the monopoly non-commitment case
Actual competition/ The entrant can price discriminate	Inefficiency: The same range as in the monopoly case under no commitment	Inefficiency: Same range in the monopoly non-commitment case
Actual competition/ The entrant cannot price discriminate	Inefficiency: The range of inefficiency is larger than the monopoly non-commitment case.	Same range of inefficiency as in the monopoly non-commitment case

4 Applications/ Conclusion

This paper serves as a small step towards understanding the role of a competitive threat in the frequency of new product introductions in durable network goods. The message of this work is that better versions of such products may arise too often and this inefficiency may be due to potential or actual competition. Going one step further, it is suggested that it may be beneficial for society if the incumbent is forbidden to commit to whether he will upgrade or not. This contrasts sharply with the monopolistic scenario where the first best is achieved under the firm's commitment power.

The model applies to scenarios where an incumbent monopolist is threatened by a potential competitor and is considering whether to upgrade his product in the subsequent period. It predicts that when entry cannot be deterred, the incumbent monopolist often commits not to upgrade. Moreover, the superior good is always introduced in the market and this may not be socially beneficial. Such a scenario may occur in technology markets where we observe frequent new versions sold either by the same firm or a competitor. A prime example that fits proposition 2 comes from the spreadsheet market for personal computers. In 1988, Lotus was the dominant player with 70% market share.[17] In 1989 it sold its software program 1-2-3 version 3 in IBM high-end computers[18] and also committed not to upgrade in the Windows platform.[19] Microsoft sold Excel 3 in 1990 offering backward compatibility to the 1-2-3 version 3, consumers switched to Excel and by 1993, Microsoft had outplaced Lotus as the market leader.[20]

Although the model matches well with the real world example identified above, there are other reasons that may affect an incumbent monopolist's decision to upgrade when he faces a competitive threat. For example, it may be the case that he is unsure about the quality improvement introduced by the competitor or even the success of his own R&D. It could also be that the success of the new platform (Windows) was ex-ante questionable. Although these situations are acknolwledged to be possible, they are not considered in this paper.

[17] See http://www.utdallas.edu/~liebowit/book/sheets/sheet.html

[18] See http://www.cs.umd.edu/class/spring2002/cmsc434-0101/MUIseum/applications/lotus123.html

[19] See http://archive.computerhistory.org/resources/access/text/2012/04/102658156-05-01-acc.pdf page 24 and http://ecommerce.hostip.info/pages/686/Lotus-Development-Corp.html

[20] See http://books.google.co.uk/books?id=8s3aAAAAMAAJ&pg=PA40&dq=january+1991 +infoworld+excel+3+vs+lotus+1-2-3+compatibility&hl=en&sa=X&ei=zubjUruJOvGf 7gbqlYDwDQ&ved=0CDsQ6AEwAw#v=onepage&q=january%201991%20infowo rld%20excel%203%20vs%20lotus%201-2-3%20compatibility&f=false and http://www.joelonsoftware.com/ articles/fog0000000052.html

5 Appendix

5.1 Market outcome/ Certain Entry/ The incumbent commits to upgrade and the entrant can price discriminate

If the incumbent commits to upgrade, in period two, perfect compatibility between the superior products and backward compatibility of the new versions ensure that the new potential customers join a network of size 1 if they buy from either the incumbent or the entrant. Their net utility if they buy either of the competitors' superior good is $q_2+\alpha-c-p_2^{'}$, $q_2+\alpha-c-p_2$ where $p_2^{'}$, p_2 are the entrant's and the incumbent's price choices, respectively. Old consumers are assumed to coordinate to a 'reluctant rule'; that is, they buy a product independently of what the other period one customers do. So, they will purchase the entrant's superior good even if all the other period one customers either stick to the incumbent's initial or upgrade version if:

$$q_2 + \alpha - c_u - p_u^{'} \geq \max\left\{q_1 + \alpha\lambda_1,\ q_2 + \alpha - c_u - p_u\right\},$$

where p_u, $p_u^{'}$ are the competitors' price choices. Since Bertrand competition drives all prices to zero, the new comers purchase the superior product for free from either of the competitors. If $\Delta q+\alpha\lambda_2-c_u<0$, the old customers stick to the incumbent's initial version. If $\Delta q+\alpha\lambda_2-c_u\geq 0$, the whole market purchases a new product from either the incumbent or the rival. Working back in the first period, the incumbent sets a price for the initial version to attract the incoming customers. If the first period potential customers buy the initial version and expect to purchase the new product in the second period (when $\Delta q+\alpha\lambda_2-c_u\geq 0$), they will do so by paying a price p_1 satisfying the equality:

$$q_1 + \delta q_2 + \alpha\lambda_1 + \delta\alpha - c - \delta c_u - p_1 = \delta(q_2 + \alpha - c)$$

or equivalently, $p_1 = q_1 + \alpha\lambda_1 - c(1-\delta) - \delta c_u$. Similarly, if old customers expect not to purcahse a new product (when $\Delta q + \alpha\lambda_2 - c_u < 0$), they are willing to pay a price p_1

such that their total expected discounted benefit from buying the initial product and not upgrading is greater than or equal to their expected surplus if they postpone their decision for period two. Thus, the equilibrium period one price is set by the incumbent monopolist such that:

$$q_1 + \delta q_1 + \alpha\lambda_1 + \delta\alpha\lambda_1 - c - p_1 = \delta(q_2 + \alpha - c),$$

or $p_1 = q_1 + \delta q_1 + \alpha\lambda_1 - \delta\alpha\lambda_2 - c(1-\delta) - \delta q_2$.

5.2 Market outcome/ Certain Entry/ The incumbent commits not to upgrade and the entrant can price discriminate

Consider now the case that the incumbent commits not to upgrade. The new customers are assumed to act as if they are a single player. Thus, their net utility if they buy the entrant's superior product is $q_2 + \alpha - c - p_2^{'}$, where $p_2^{'}$ is her price choice. If they all decide to purchase the incumbent's initial version, their net utility is $q_1 + \alpha\lambda_2 + \alpha\lambda_1 x_1 - c - p_1^{'}$, where x_1 is the old customers' fraction that sticks to the old product and $p_1^{'}$ is his price choice. Thus, the new comers will decide to purchase the entrant's good if:

$$q_2 + \alpha - c - p_2^{'} \geq q_1 + \alpha\lambda_2 + \alpha\lambda_1 x_1 - c - p_1^{'}$$

Old customers prefer the entrant's version even if all the other first period consumers stick to the old product if:

$$q_2 + a - c_u - p_u^{'} \geq q_1 + \alpha\lambda_1 + \alpha\lambda_2 x_2,$$

where x_2 is the new consumers' fraction that buys the old good and $p_u^{'}$ is the entrant's price choice. If $\Delta q + \alpha\lambda_2 - c_u < 0$, old customers don't buy the new product independently of the entrant's price choice. Bertrand competition leads to prices $p_2^{'} = \Delta q$, $p_1^{'} = 0$, $p_u^{'} = 0$ and the new customers purchase the new product. If $\Delta q + \alpha\lambda_2 - c_u \geq 0$, Bertrand competition leads to equilibrium prices $p_2^{'} = \Delta q + \alpha\lambda_1$, $p_1^{'} = 0$, $p_u^{'} = \Delta q + \alpha\lambda_2 - c_u$ and all the customers buy the new product. Going back to the initial period, the incumbent sets a price to attract the first period potential customers whose outside opportunity is to wait and make their purchase in the second period by paying a price Δq. If they expect that they will buy the superior product in the following period (when $\Delta q + \alpha\lambda_2 - c_u \geq 0$), they are willing to buy the initial version if their expected total net benefit is higher than their discounted payoff from postponing their decision for the following period. Thus, the total price they are willing to pay $(p_1 + \delta p_u^{'})$ is given by the equality:

$$q_1 + \delta q_2 + \alpha\lambda_1 + \delta\alpha - c - \delta c_u - \delta(q_2 + \alpha - c - \Delta q) = p_1 + \delta p_u^{'},$$

or equivalently $p_1 = q_1 + \delta q_2 + \alpha\lambda_1 + \delta\alpha - c - \delta c_u - \delta(q_2 + \alpha - c - \Delta q) - \delta(\Delta q + \alpha\lambda_2 - c_u) = q_1 + \alpha\lambda_1 - c(1-\delta) - \delta\alpha\lambda_2$. If old customers expect to stick to the old product (when $\Delta q + \alpha\lambda_2 - c_u < 0$), they are willing to buy the initial product by paying a price p_1 that satisfies the equality:

$$q_1 + \delta q_1 + \alpha\lambda_1 + \delta\alpha\lambda_1 - c - p_1 = \delta(q_2 + \alpha - c - \Delta q)$$

or $p_1 = q_1 + \alpha\lambda_1 - \delta\alpha\lambda_2 - c(1-\delta)$.

5.3 Market outcome/ Certain Entry/ Incumbent's Commitment/ No price discrimination

If the incumbent commits to upgrade, perfect compatibility between the superior products and backward compatibility of the new version ensure that the new potential customers join a network of size 1 if they buy from either the incumbent or the entrant. Their net utility if they buy the entrant's or the incumbent's superior good is $q_2 + \alpha - c - p_2^{'}$, $q_2 + \alpha - c - p_2$ where $p_2^{'}$, p_2 are the entrant's and the incumbent's price choices, respectively. Old date t=2 consumers buy the entrant's product even if all the other customers of their group either stick to the incumbent's initial or buy his upgrade version if:

$$q_2 + \alpha - c_u - p_2^{'} \geq \max\{q_1 + \alpha\lambda_1,\ q_2 + \alpha - c_u - p_u\},$$

where p_u is the incumbent's price choice for the old consumers who upgrade in period two. Bertrand competition drives all the prices to zero. If $\Delta q + \alpha\lambda_2 - c_u < 0$, the old customers stick to the incumbent's initial version and the new comers purchase the superior good for free by either of the competitors. If $\Delta q + \alpha\lambda_2 - c_u \geq 0$, the whole market purchases for free either the incumbent's or the entrant's high-quality product. In the first period, the incumbent sets a price for the initial version to attract the incoming customers. If the old consumers expect to purchase a new product in the second period ($\Delta q + \alpha\lambda_2 - c_u \geq 0$), the price in the first period satisfies the equality:

$$q_1 + \delta q_2 + \alpha\lambda_1 + \delta\alpha - c - \delta c_u - p_1 - \delta p_u = \delta(q_2 + \alpha - c - p_2^{'})$$

or equivalently, $p_1 = q_1 + \alpha\lambda_1 - c(1-\delta) - \delta c_u$, where $p_u = p_2^{'} = 0$. If these customers expect to keep the initial version (when $\Delta q + \alpha\lambda_2 - c_u < 0$), the first period price satisfies the equality:

$$q_1 + \delta q_1 + \alpha\lambda_1 + \delta\alpha\lambda_1 - c - p_1 = \delta(q_2 + \alpha - c),$$

or $p_1 = q_1 + \delta q_1 + \alpha\lambda_1 - \delta\alpha\lambda_2 - c(1-\delta) - \delta q_2$.

Consider now the case that the incumbent commits not to upgrade. The new customers choose the entrant's superior good if:

$$q_2 + \alpha - c - p_2^{'} \geq \max\left\{q_1 + \alpha\lambda_2 + \alpha\lambda_1 x_1 - c - p_1^{'}, 0\right\}$$

where $p_2^{'}$, $p_1^{'}$ are the entrant's and the incumbent's second period price choices for the high and the initial version, respectively. Old consumers prefer the entrant's version and do not stick to the incumbent's initial product if:

$$q_2 + a - c_u - p_2^{'} \geq q_1 + \alpha\lambda_1 + \alpha\lambda_2 x_2$$

or equivalently

$$\Delta q + \alpha\lambda_2 - \alpha\lambda_2 x_2 - c_u - p_2^{'} \geq 0,$$

where x_2 is the new consumers' fraction that buys the old good. If $\Delta q + \alpha\lambda_2 - c_u \geq 0$, $\Delta q > \Delta q + \alpha\lambda_2 - c_u$, $\Delta q + \alpha\lambda_2 - c_u \geq \lambda_2 \Delta q$, Bertrand competition leads to $p_2^{'} = \Delta q + \alpha\lambda_2 - c_u$ and $p_1^{'} = 0$ and the equilibrium market outcome is that everyone purchases the entrant's new product. Otherwise, the prices are $p_2^{'} = \Delta q$ and $p_1^{'} = 0$ with potentially different equilibrium market outcomes dependent on the parameter values. To be more precise, if $\Delta q + \alpha\lambda_2 - c_u < 0$ or if $\Delta q + \alpha\lambda_2 - c_u \geq 0$, $\Delta q > \Delta q + \alpha\lambda_2 - c_u$, $\Delta q + \alpha\lambda_2 - c_u < \lambda_2 \Delta q$, unlike the old consumers, the new comers purchase the entrant's superior product, whereas if $\Delta q + \alpha\lambda_2 - c_u \geq 0$, $\Delta q < \Delta q + \alpha\lambda_2 - c_u$, everyone buys the new product in the second period. In the initial stage, the incumbent sets a price p_1 for the lower quality good such that the potential customers buy it and do not postpone their purchase decision. First period customers' outside opportunity is to purchase the superior entrant's product by paying a price $p_2^{''} = \Delta q$ in the future period. If they expect to buy the higher quality product, ($\Delta q + \alpha\lambda_2 - c_u \geq 0$, $\Delta q > \Delta q + \alpha\lambda_2 - c_u$, $\Delta q + \alpha\lambda_2 - c_u \geq \lambda_2 \Delta q$), the first period price satisfies the equation:

$$q_1 + \delta q_2 + \alpha\lambda_1 + \delta\alpha - c - \delta c_u - p_1 - \delta p_2^{'} = \delta(q_2 + \alpha - c - p_2^{''}), \text{ where } p_2^{'} = \Delta q + \alpha\lambda_2 - c_u, \ p_2^{''} = \Delta q$$

or equivalently $p_1 = q_1 + \alpha\lambda_1 - c(1-\delta) - \delta\alpha\lambda_2$. They also expect to buy q_2 if $\Delta q + \alpha\lambda_2 - c_u \geq 0$, $\Delta q < \Delta q + \alpha\lambda_2 - c_u$. In this case, the first period price is given by the equality:

$$q_1 + \delta q_2 + \alpha\lambda_1 + \delta\alpha - c - \delta c_u - p_1 - \delta p_2^{'} = \delta(q_2 + \alpha - c - \Delta q), \text{ where } p_2^{'} = \Delta q$$

or $p_1 = q_1 + \alpha\lambda_1 - c(1-\delta) - \delta c_u$. If the old customers expect to stick to the old version (if $\Delta q + \alpha\lambda_2 - c_u < 0$ or if $\Delta q + \alpha\lambda_2 - c_u \geq 0$, $\Delta q > \Delta q + \alpha\lambda_2 - c_u$, $\Delta q + \alpha\lambda_2 - c_u < \lambda_2 \Delta q$), the first period price satisfies the equation:

$$q_1 + \delta q_1 + \alpha\lambda_1 + \delta\alpha\lambda_1 - c - p_1 = \delta(q_2 + \alpha - c - \Delta q)$$

and thus, $p_1 = q_1 + \alpha\lambda_1 - c(1-\delta) - \delta\alpha\lambda_2$.

5.4 Post Entry game/ Potential entry/ The incumbent commits to upgrade

Think of the hypothetical post-entry scenario when the entrant needs to bear a fixed positive development cost when the incumbent commits to upgrade. Note that I consider the case where the entrant is able to price discriminate between the old and the new users. Under the assumption of compatibility between the rival firms' products, the new customers' net utility if they buy the high-quality product by either the incumbent or the entrant is $q_2 + \alpha - c - p_2$, $q_2 + \alpha - c - p_2^{'}$, respectively. Old customers buy the new product even if every other old customer either chooses the entrant's high-quality or the incumbent's initial version when:

$$q_2 + \alpha - c_u - p_u \geq \max\left\{q_2 + \alpha - c_u - p_u^{'},\ q_1 + \alpha\lambda_1\right\}.$$

where p_u, $p_u^{'}$ are the the competitors' price choices and because they expect the new second period customers to purcahse a new version. If $\Delta q + \alpha\lambda_2 - c_u < 0$, the old consumers will not buy the upgraded version independently of the rival firms' price choices. Bertrand competition leads to prices, $p_2 = \frac{F}{\lambda_2} - \epsilon$[21], $p_2^{'} = \frac{F}{\lambda_2}$.[22] New customers would purchase the superior good from the incumbent and thus, the potential entrant would incur losses after

[21] For ϵ being any small positive number

[22] When, without loss of generality, I assume that the development cost is not prohibitively high: $F < (q_2 + \alpha\lambda_2 - c_u)\min\{\lambda_1, \lambda_2\}$.

entry. Thus, she will optimally choose not to invest. Similarly, think of the post-entry game if $\Delta q + \alpha\lambda_2 - c_u \geq 0$. Bertrand competition would lead to prices $p_2 = \frac{F}{\lambda_2} - \epsilon$, $p_2^{'} = \frac{F}{\lambda_2}$, $p_u = \frac{F}{\lambda_1} - \epsilon$, $p_u^{'} = \frac{F}{\lambda_1}$ and the whole marketwould upgrade. Thus, the potential entrant would be better-off if she stayed out of the market. Going back to the first period, the incumbent needs to attract the potential customers into buying the initial version of the product. If the first period customers expect to upgrade (when $\Delta q + \alpha\lambda_2 - c_u \geq 0$), the first period price is given by the expression:

$$p_1 = q_1 + \alpha\lambda_1 - c + \delta q_2 + \delta\alpha - \delta c_u - \delta p_u,$$

where $p_u = \Delta q + \alpha\lambda_2 - c_u$. If they expect to stick to the old version (when $\Delta q + \alpha\lambda_2 - c_u < 0$), the first period price p_1 is such that:

$$p_1 = q_1 + \delta q_1 + \alpha\lambda_1 + \delta\alpha\lambda_1 - c.$$

5.5 Post entry game/ Potential entry/ The incumbent commits not to upgrade

I analyze the scenario where the entrant can price discriminate between the different consumers' classes.

Case 1 $\Delta q + \alpha\lambda_2 - c_u < 0$, $\lambda_2\Delta q - F \geq 0$.

In the second period, Bertrand competition leads to the entrant's and the incumbent's prices being $p_2^{'} = \Delta q$, $p_1^{'} = 0$, respectively and only the new potential customers purchase the superior product. The incumbent in period one sets a price p_1, such that:

$$q_1 + \alpha\lambda_1 + \delta q_1 + \delta\alpha\lambda_1 - c - p_1 \geq \delta(q_2 + \alpha - c - p_2^{''}),$$

where the left hand side of the inequality is the customers' net utility from purchasing the lower quality good in period one and retaining it in period two. Note that if all consumers postpone their purcahse, the price they would face is $p_2^{''} = \Delta q$. Thus, the first period price satisfies the above inequality as equality and is given by the expression:

$$p_1 = q_1 - (1-\delta)c + \alpha\lambda_1 - \delta\alpha\lambda_2.$$

The incumbent's and the entrant's equilibrium profits are:

$$\begin{aligned} \Pi_I &= \lambda_1[q_1 - (1-\delta)c + \alpha\lambda_1 - \delta\alpha\lambda_2], \\ \Pi_E &= \lambda_2\Delta q - F,\ \lambda_2\Delta q - F \geq 0, \end{aligned}$$

respectively.

Case 2 $\Delta q + \alpha\lambda_2 - c_u \geq 0,\ \lambda_1(\Delta q + \alpha\lambda_2 - c_u) + \lambda_2(\Delta q + \alpha\lambda_1) - F \geq 0.$

In the second period, Bertrand competition leads to the prices $p_2^{'} = \Delta q + \alpha\lambda_1,\ p_u^{'} = \Delta q + \alpha\lambda_2 - c_u$, set by the entrant and $p_1^{'} = 0$ set by the incumbent and everyone purchases the entrant's superior good. Initially, the incumbent sets a price p_1, such that:

$$q_1 + \delta q_2 + \alpha\lambda_1 + \delta\alpha - c - \delta c_u - p_1 - \delta p_u^{'} \geq \delta(q_2 + \alpha - c - p_2^{''}),$$

where $p_2^{''} = \Delta q$ is the entrant's price if the old customers wait and purchase the superior product in the second period. Thus, the equilibrium prices as well as the competitors' profits are given by the expressions:

$$p_1 = q_1 + \alpha\lambda_1 - c(1-\delta) - \delta c_u,\ p_u^{'} = \Delta q + \alpha\lambda_2 - c_u,\ p_1^{'} = 0,\ p_2^{'} = \Delta q + \alpha\lambda_1.$$

$$\Pi_I = \lambda_1[q_1 + \alpha\lambda_1 - c(1-\delta) - \delta c_u],$$
$$\Pi_E = \lambda_1(\Delta q + \alpha\lambda_2 - c_u) + \lambda_2(\Delta q + \alpha\lambda_1) - F.$$

5.6 No commitment/ Potential Entry

The entrant firm would not invest in developing the higher quality good. To see this fact, consider the post entry game. The incumbent would be indifferent between selling the lower or the superior product because (due to Bertrand competition) his profits would be zero in both cases. He would then prefer to upgrade, because this would guarantee that the entrant would incur losses. The potential entrant anticipates the incumbent's post entry behaviour and she rationally does not pay the fixed development cost. This fact allows the incumbent to be the sole supplier of the upgrade in the second period.

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