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Compatibility, Intellectual Property, Innovation and Efficiency in Durable Goods Markets with Network Effects

Thanos Athanasopoulos

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Compatibility, Intellectual Property, Innovation and Efficiency in Durable Goods Markets with Network Effects

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March 27, 2014[2]

Abstract

This paper analyses firms' behaviour towards compatibility and the relation of these decisions with their incentives to invest into improving their durable, network goods. By using a sequential game where the dominant firm plays first, we give its competitor the ability to build on innovations previously introduced by the market leader. Recognizing the intertemporal linkage in forward looking customers' purchasing choices, we find that in anticipation of a relatively large quality improvement by the rival, strategic pricing leads the dominant firm to support compatibility even if it could exclude its rivals by using a patent for its invention. Furthermore, not only doesn't interoperability de-facto maximise social welfare but we also identify no market failure when network effects are not particularly strong.

Keywords: Firms, Pricing, Compatibility, Innovation, Technological Change, Intellectual Property Rights, Antitrust Law, Competition, Externalities, Product Durability, Welfare

JEL classification: D43, L13, D71, D62, L15, L4, K21, L51, O34, O31.

1 Introduction

Should dominant firms in economies with durable, network goods like software markets, have the duty to provide technical compatibility information to direct competitors? This

[1]Department of Economics; University of Warwick.

[2]I would like to express my gratitude to Claudio Mezzetti and Daniel Sgroi for all the fruitful conversations we had. All the errors in this work are solely mine.

fundamental question lies at the intersection of Antitrust and Intellectual Property Law and different countries give different answers.

The proponents of interoperability[3] argue that its presence guarantees that consumers' welfare is maximised at least in a static scenario. This is the dominant view in the European Union where market leaders should provide compatibility information to rivals as failure to do so is considered as a potential violation of Article 102 (ex article 82) of the European Competition Law and leads to regulation by Courts enforcing the dominant firms to allow compatibility[4]. A famous example comes from the most recent European Commission case against Microsoft in 2008. It was related to the computer software giant's refusal to provide its competitors technical information regarding its Office suite so that they could craft software interoperable with Microsoft Office 2007[5]. The case followed a complaint[6] from firms-members of the ECIS (European Committee of Interoperable Systems) and was put on hold in December 2009 after Microsoft's commitment to comply with the European Union Competition Law[7]. Nevertheless, there are other important cases where the Commission and European Courts ruled favouring a weaker protection for Intellectual Property Rights owners. In Magill, the Commission found that the refusal by broadcasting companies to license information protected by Copyright constituted an abuse of a dominant position. This decision was upheld by the European Court of Justice which stated that although the refusal to license copyright and lists of television programmes was not, per se, an abuse of a dominant position, the "exercise of an exclusive right by the proprietor may, in exceptional circumstances, involve abusive conduct". The Court found that the exceptional circumstances involved the introduction of a new product which consumers wanted and the refusal to license blocked its emergence. Thus, broadcasters were required to supply copyrighted program schedules to a would-be supplier of a new product, not offered by the copyright

[3] We use the terms interoperability, compatibility and connectivity interchangeably throughout the paper.
[4] See http://ec.europa.eu/competition/antitrust/legislation/handbook_vol_1_en.pdf
[5] See http://europa.eu/rapid/press-release_MEMO-08-19_en.htm

[6] See http://www.techhive.com/article/124813/article.html
[7] See http://europa.eu/rapid/press-release_IP-09-1941_en.htm?locale=en

owners, for which the schedule information was indispensable[8]. This was the first case that tipped the balance in Europe between the Competition Law and the Intellectual Property Law in favour of the former. In the case of IMS which is in the business of providing information to the pharmaceutical industry on sales of pharmaceutical products in Germany, the Commission and the Court of Justice faced the issue of whether a dominant service provider could refuse to license an input that is a de-facto industry standard. The Court of Justice affirmed that it is sufficient for the license applicant to satisfy the three "cumulative" Magill conditions. Thus, the refusal to license Intellectual Property may, in itself, constitute a breach of Article 82 where a) access is indispensable for carrying on a particular business, b) resulting in the elimination of competition on a secondary market and c) preventing the emergence of a new product for which there is potential consumer demand[9]. Conclusively, refusing a license to prevent price competition is not considered, per se, as abusive, whereas refusing a license with the effect of preventing innovation is. It also remains a requirement of the Magill test that denial of the license renders the introduction of the new product impossible.

On the other hand, there are voices which argue that by giving up intellectual property rights, dominant firms' incentives for innovation would be curbed. Among them, Thomas Barnett of the United States Department of Justice argues that: "U.S. courts recognize the potential benefits to consumers when a company, including a dominant company, makes unilateral business decisions, for example to add features to its popular products or license its intellectual property to rivals, or to refuse to do so"[10]. Indeed, the U.S antitrust authorities conclude that "antitrust liability for mere unilateral, unconditional refusal to license patents will not play a meaningful part in the interface between patent rights and antitrust protections"[11].

[8] See http://www.panix.com/~jesse/magill.html

[9] For more details on the IMS case see http://www.mofo.com/judgment-of-european-court-of-justice-in-ims-health-v-ndc-health-05-18-2004/

[10] See http://www.justice.gov/atr/public/press_releases/2007/226070.htm

[11] See http://www.justice.gov/atr/public/reports/236681_chapter7.htm

Therefore, investigating firms' attitude towards interoperability and how these decisions are related with their incentives to invest into improving the existing technology is very important and this paper provides such an investigation. More precisely, it provides some answers to the following questions: Will the dominant firm block interoperability with its rivals or equivalently is exclusivity always generated in an unregulated market? Even if there is incompatibility, does this de-facto mean that it is socially undesirable? Could a market that compatibility is voluntary converge to interoperability when this is socially efficient?

To answer these questions, a sequential game is built where two firms take turns in deciding whether to invest in quality and allow interoperability with their rival. This model fits a common pattern in durable, technology goods markets where the smaller rival may have valuable ideas that emerge as follow-on innovations after the dominant firm's invention hits the market in a Schumpeterian scenario of creative destruction. Our analysis shows that the dominant firm supports compatibility even if it could use a patent and exclude rivals when the anticipated future quality improvement by the rival is relatively large. This is because strategic pricing allows the market leader to extract more of the higher future surplus in the present market. Regarding welfare, we find that mandated compatibility by Antitrust Bodies may lead to the inefficient introduction of a negligibly innovative product while the market where connectivity is not mandatory would maintain the previous version. On the other hand, when network effects are strong, a market where unilateral refusals to supply interoperability are not ruled out by Competition Law could potentially lead to inefficient technological slowdown. When network effects are weak, a laissez faire competition policy towards the exercise of IPRs leads to social efficiency and existing consumers are not better-off when interoperability is enforced. Our conclusions cast some doubts on whether mandatory interoperability, while trying to protect consumers from abusive behaviour, actually distorts the market and leads to socially undesirable results without benefiting them.

1.1 Related Literature

This paper contributes first to the literature regarding firms' incentives towards compatibility with their competitors. In a seminal paper, Katz and Shapiro (1985) show that firms with a larger installed base will prefer to be incompatible with their rivals. In the same vein, Cremer, Rey and Tirole (2000) analyze the competition between Internet backbone providers and predict that a dominant firm may want to reduce the degree of compatibility with smaller market players. Malueg and Schwartz (2006) find that a firm with the largest installed base will choose not to support connectivity with firms that are themselves compatible when its market share exceeds fifty percent or the potential to add consumers falls. A similar result appears in Chen, Doraszelski and Harrington (2007) who consider a dynamic setting with product compatibility and market dominance. They find that if a firm gets a larger market share, it may make its product incompatible. On the other hand, when firms have similar installed bases, they make their products interoperable in order to expand the market. Viecens (2009) differentiates between direct and indirect network effects by studying platform competition between two firms where users buy a platform and its compatible applications. By allowing for applications to be substitutes, complements or independent, she considers compatibility in two dimensions. First, compatibility of the complementary good, which she calls compatibility in applications. Second, she considers inter-network compatibility where direct network externalities are present. She finds that the dominant firm will never promote compatibility in applications. In contrast, both firms find inter-network compatibility profitable. Focusing on direct network effects and durable goods and contrary to the literature, we find that the dominant firm may support connectivity with its rival. This happens when the quality improvement expected to be introduced by the smaller firm is substantial.

Regarding welfare, Economides (2006) argues that it is socially efficient to move towards compatibility and similarly, Katz and Shapiro (1985) show that interoperability would raise consumers' surplus. In a static environment, Viecens (2009) concludes that compatibility in

the applications may be harmful for users and social welfare, particularly when asymmetries are strong. Moreover, inter-network compatibility should not be supported by consumers. We find that interoperability could lead to dynamic inefficiency depending on the industry characteristics that are observable or can be estimated. Unlike an unregulated market, a regime of compulsory compatibility may result in the inefficient introduction of the higher quality product while society would be better-off without it. This occurs when innovation happens with certainty and if the expected quality improvement is relatively small.

The second strand of literature that this paper relates to, has to do with firms' incentives to upgrade their durable, network goods and how these decisions affect social welfare. In a monopolistic environment, Ellison-Fudenberg (2000) show that upgrades may occur too frequently due to the firm's inability to commit to whether it will choose to upgrade in the future or not. Athanasopoulos (2013) extends Ellison-Fudenberg (2000) to a potential entry scenario where compatibility between the rival firms'products is the status quo. He shows that the incumbent's commitment power adds an additional source of inefficient upgrading while potential or actual competition can harm social optimality. The present paper indicates that in an unregulated market, the social and the private firms' incentives for upgrading are aligned when quality improvements occur with certainty.

In the literature regarding sequential innovation, Scotchmer (1991, 1996), Scotchmer and Green (1996) among others also study the case of single follow-on innovations. They focus on the breadth and length of patents needed to secure the initial innovator's incentives to innovate when a second innovator threatens to innovate as well. They hold the view that patents for the first innovator should last longer when a sequence of innovative activity is undertaken by different firms compared to the case that innovation is concentrated in one firm. On the other hand, we are mainly interested in the interplay between IPRs protection through patents with firms' behaviour towards compatibility. Contrary to the papers addressed previously, we find that the first innovator will voluntarily offer compatibility to rivals even if he can potentially use a patent because strategic pricing enables him to absorb

more of the second period expected profit when he anticipates a large improvement from the second innovator. In a related paper, Maskin and Bessen (2009) find that when innovation is sequential, patent protection is not as useful for encouraging innovation as in a static setting. Our work shows that although the innovation incentives may indeed be curbed for the smaller rival under a laissez faire Competition Law towards the exercise of IPRs, this fact may be socially beneficial. We also depart from all the papers above by considering a market with durable, network goods and also the role of existing consumers in the determination of social efficiency.

2 The Model

Consider an industry where a durable, network good is currently supplied by the dominant market player. He needs to pay a fixed cost to improve his product quality and must also decide whether to support interoperability with his competitor. When facing this set of choices, the firm knows that in the subsequent period its rival will face a decision whether to invest and allow connectivity.

A few remarks regarding compatibility are important. Following Malueg and Schwartz (2006), compatibility in an unregulated economy requires both parties' consent and cannot be achieved unilaterally by using converters or adapters. In particular, in software, office suites markets, interoperability is accomplished through the relevant parties' dissemination of interface information and through supporting a pre-existing Open Standard. Note that licensing of Intellectual Property through inter-firm payments for compatibility is not allowed and the rationale behind this decision is simple: royalties may lead to exclusion or collusion and they are often ruled out by regulation[12]. In a nutshell, the choice of compatibility involves no additional cost or benefit both for the market leader and the smaller competitor. Further to that and if connectivity is supported bilaterally, backward compatibility makes

[12]The case that (F)RAND (Fair, reasonable and non-discriminatory) payments are allowed between firms that participate in Cooperative Standards Settings Organizations will be considered in future work.

the upgraded good buyers able to open and save a document that was created with the lower quality product while non-forward compatibility prevents the purchasers of the initial versions from working with documents that are created with the upgrades.

The model is cast in discrete time and the sequence of events in the supply side is as follows: originally ($t = 0$) there is no market as existing consumers (λ_0) have purchased the initial version of quality q_0 in a past date and the dominant firm pays a fixed amount F ($F > 0$) for the improvement of his product quality from q_0 to q_1[13]. At the beginning of the first period ($t = 1$), the market leader sets the price(s) for his product(s) and decides whether to support compatibility by eliciting interoperability information about its version. In the scenario he decides not to support compatibility, he can use a short-lived patent for his invention that lasts until the second period. Note that as explained in the Introduction, Article 102 of the European Union Competition Law (and in sharp contrast with the U.S Antitrust Law) is considered to be potentially violated if the dominant firm refuses to reveal interoperability information to rivals and in such a case, regulation leads to the enforcement of compatibility. In the second stage of the first period, the competitor must decide whether to invest a fixed amount F ($F > 0$) to create a follow-on product of higher expected quality q_2^e. If she invests, Bertrand competition follows in the second period ($t = 2$) between the rivals while if she doesn't, the dominant firm remains the sole supplier in the market. When interoperability is not mandatory and following the market leader's decision of supporting compatibility, the smaller rival also needs to decide whether she allows backward compatibility with the dominant firm's previous version (q_1). It is important to stress that the dominant firm's potential choice of not supporting compatibility in a market that operates under a laissez faire Competition Law towards the exercise of IPRs does not, per se, deter the smaller rival from investing towards a better expected quality q_2^e. This happens as information about the product of quality q_1 is disseminated freely when it hits the market and the rival can still use the Open Document Format to make a better product which will

[13]Our results would not change even if investing for the market leader becomes a decision and is not considered as just a cost.

be incompatible with q_1. Moreover, products are durable and in particular, all versions are assumed functional for two periods. Since price discrimination between the old and the new consumers is possible, both the market leader (at $t = 1$) and the rival (at $t = 2$) have the ability to offer upgrade prices to old users. Also note that firms are risk neutral and the marginal cost of production is normalized to zero for all products.

On the demand side, consumers are identical and while at first ($t = 0$) there is a mass λ_0 of customers in the economy, future generations arrive in constant flows λ_t ($t = 1, 2$). Their utility is linear in income and partially dependent on network effects captured by a parameter α. So, if the buyer joins a network of mass x, the network benefit is αx. In addition to the monetary cost, consumers also incur a learning cost c the first time they start to use the product followed by an upgrade cost c_u (where $c_u < c$) when learning to use the new version(s) but without bearing any switching costs.

Customers present in the first period are forward looking and base their purchasing decisions on the products available and their prices as well as on their expectations. These expectations reflect the information they have regarding the future quality improvement, the market size and future prices at the time they are called to make their decision and are fully aligned in equilibrium. Unlike new customers (λ_1) who cannot postpone their purchase, old users (λ_0) are not guaranteed to buy the new generation because of the durability of the version they already own. Old customers' (λ_0) purchasing decisions given announced prices resemble a coordination game and although it can have multiple equilibria, we assume they coordinate to the Pareto optimal outcome. The same rule holds for the old consumers in the second period ($\lambda_0 + \lambda_1$) if the rival introduces the version of quality q_2^e in the market. In the similar coordination problem related to the new customers' purchasing decisions, the standard assumption is that buyers with the same preferences act as if they were a single player. Thus, after observing the available products and their prices, new customers in any period (λ_1, λ_2 in the first and the second period, respectively) coordinate to what is best for all of them. All consumers make their purchasing decisions simultaneously. Also note that

the same discount factor δ applies to all the agents in the economy.

Figure 1 summarizes the timing of the model and the agents' moves.

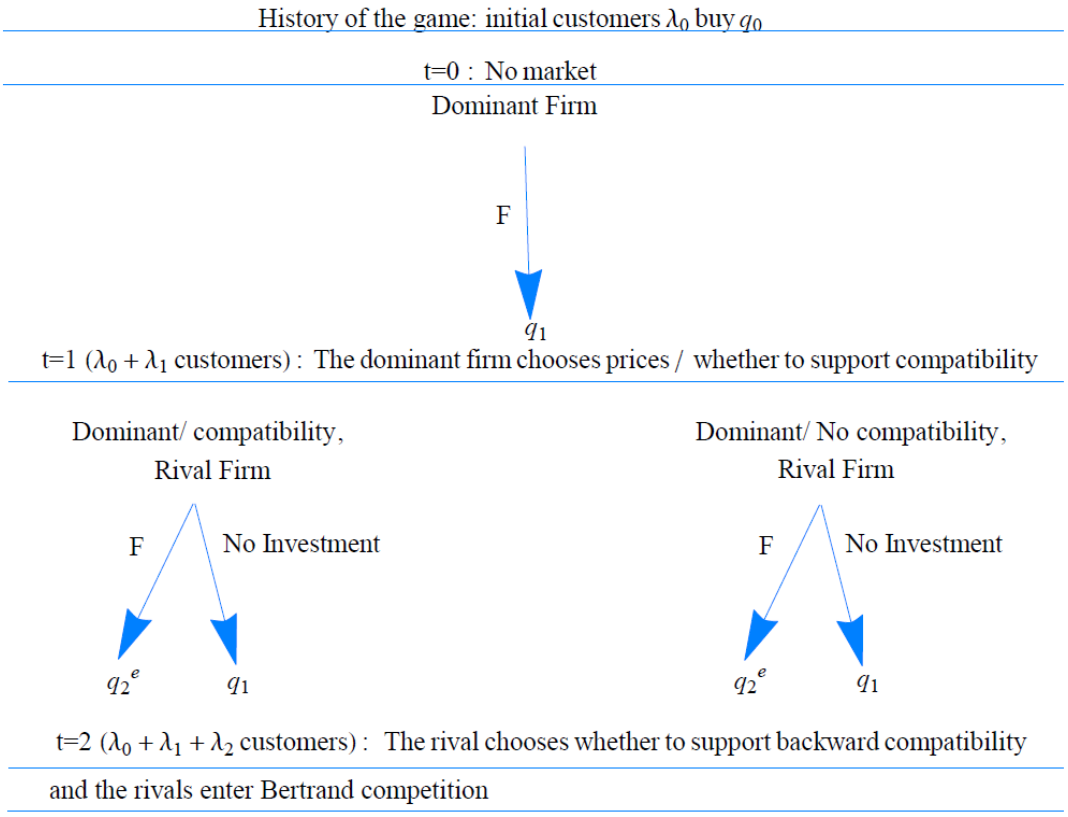

Figure 1: Timing of the agents'moves. Note that at t = 1, the dominant firm's potential refusal to allow compatibility leads to regulation in the European Union mandating interoperability (and thus, q_2^e and q_1 being compatible). On the other hand, in the US, the same dominant firm's choice would lead to q_2^e and q_1 being incompatible.

3 Results

3.1 Market outcome

In this section, we explore the private firms' incentives towards investing in quality and supporting interoperability as well as their optimal pricing decisions. The next assumptions hold throughout the paper:

A1 Let $\Delta q = q_1 - q_0$, $\Delta q^e \leq q_2^e - q_1$ denote the quality differential in the first and the expected quality improvement in the second period, respectively. We assume: $\Delta q^e \leq \Delta q$.

A2 $\Delta q^e + \alpha\lambda_2 - c_u \geq 0$.

A3 $\Delta q^e + \alpha\lambda_2 - \alpha(\lambda_0 + \lambda_1) - c_u < 0$ or $\Delta q^e < \overline{v}$.

A4 $F < \lambda_2 \Delta q^e$, $F < \lambda_2[\Delta q^e - \alpha(\lambda_0 + \lambda_1)]$ when $\Delta q^e \geq \alpha(\lambda_0 + \lambda_1)$.

In the context of sequential innovation and to stress that innovative ideas become more difficult with time, we assume that a given investment is expected to lead to a smaller quality improvement in the future compared to the first period. The second inequality ($\Delta q^e + \alpha\lambda_2 - c_u \geq 0$) says that even for negligible quality improvements, the market is growing sufficiently quickly so that old customers in the second period ($\lambda_0 + \lambda_1$) are expected to be better-off if they upgrade to the new generation q_2^e when compatibility is present. The third inequality ($\Delta q^e + \alpha\lambda_2 - \alpha(\lambda_0 + \lambda_1) - c_u < 0$) stresses that the expected quality improvement is bounded. Both these last two assumptions reduce the number of possible cases without affecting our results. Note that unless we assume that the values of the development cost are relatively small, the smaller firm would not invest which would not be an interesting scenario to analyze.

In a regime of mandatory connectivity, backward compatibility with the dominant firm's product enables the rival to benefit by introducing even a slightly better product of quality q_2^e[14]. Note that in both economies where firms have the duty to supply interoperability information to rivals or not, it is to the market leader's advantage to stop selling his old version in the first period because otherwise, keeping it in the market would cannibalize his first period profits. The next proposition summarizes the market outcome in an economy where compatibility is mandatory:

Proposition 1 *Under assumptions A2, A4 and in equilibrium, the dominant firm decides to stop selling the old product of quality q_0 in the first period and instead, it sells the product*

[14] See the Appendix for the analytical characterization of the market outcome under the interoperability regime.

q_1 to the new and the old first period customers. In the second period, the product of quality q_2^e is sold by the rival to the whole market. In particular, old customers ($\lambda_0 + \lambda_1$) upgrade for free.

In a laissez faire competition policy towards the exercise of IPRs, the competitor supports interoperability if the leader has already chosen to allow connectivity. This occurs because the resulting bigger network under compatibility in the second period allows the competitor to charge a higher price to potential customers. On the other hand, the rival may be deterred to invest if the dominant firm doesn't support compatibility[15]. Depending on the quality improvement expected to be introduced by the competitor (Δq^e) and for different values of the investment (F), we identify the following three assumptions and their respective scenarios that lead to different equilibrium market outcomes:

A5 $\Delta q^e - (\lambda_0 + \lambda_1)c_u < F < (\lambda_0 + \lambda_1)(\Delta q^e + \alpha\lambda_2 - c_u)$. This scenario implies that the expected quality improvement in the second period is relatively small ($\Delta q^e < \alpha(\lambda_0 + \lambda_1)$).

A6 $F \leq \Delta q^e - (\lambda_0 + \lambda_1)c_u$, $\Delta q^e \geq \alpha(\lambda_0 + \lambda_1)$. This scenario occurs when the quality differential anticipated to be introduced by the competitor is relatively large.

A7 $F \leq \Delta q^e - (\lambda_0 + \lambda_1)c_u$, $\Delta q^e < \alpha(\lambda_0 + \lambda_1)$. This scenario necessarily implies that the network parameter is greater than the upgrading cost ($\alpha \geq c_u$).

The next proposition summarizes the market equilibrium outcome in the economy that operates under a laissez faire Competittion Law towards the exercise of IPRs:

Proposition 2 *(a) If assumptions A1-A5 hold, in equilibrium, the dominant firm does not support compatibility with its rival who is deterred to invest and all customers purchase the product of quality q_1.(b) If assumptions A1-A4 and A6 hold, in equilibrium, both competitors support compatibility. In the first period, all customers use q_1 and in the second, the whole market purchases the product of quality q_2^e.*

[15]See the Appendix for the analytical characterization of the market outcome under the non-interoperability regime.

Think first of (a) where the quality improvement expected to be introduced by the competitor is relatively small ($\Delta q^e < \alpha(\lambda_0 + \lambda_1)$). By not supporting compatibility, the dominant firm deters the rival from investing and when product functionality cannot be imitated, this allows him to be the sole supplier in the second period. But this is not a sufficient condition for not supporting compatibility as the dominant firm impedes interoperability even if product functionality could be copied. To see this fact, think of the old customers in the first period (λ_0). They are ready to pay more in the first period if the dominant firm does not allow compatibility with the rival mainly because the quality improvement under a regime of no compatibility (Δq) is larger compared to the case that interoperability is present (Δq^e). The relatively small second period quality differential if compatibility is supported also makes the new customers in the first period (λ_1) willing to pay less if compatibility is allowed because the cost of upgrading is larger than the expected quality improvement. On the other hand, in (b), the expected quality differential by the competitor is large ($\Delta q^e \geq \alpha(\lambda_0 + \lambda_1)$) and the rival firm will unambiguously invest introducing the product of quality q_2^e in the market in the second period. In anticipation of this fact, the dominant firm's optimal strategy is to offer connectivity under a free licensing scheme to its competitor because it can absorb in the first period more of the expected discounted future total surplus which is higher when compatibility is present.

3.2 Social optimum

It is important to analyze the social efficiency of the results obtained previously and this section considers the problem faced by a planner that maximizes social surplus.

In general, the planner desires compatibility between rival firms' products because due to network effects, customers' utility and social welfare is maximised when interoperability

is present. After normalizing the market size in the second period to unity ($\lambda_0+\lambda_1+\lambda_2=1$) and if the product of quality q_1 is sold in both periods, social welfare is:

$$W_N = \lambda_0[q_1+\delta q_1+\alpha(\lambda_0+\lambda_1)+\delta\alpha-c_u]+\lambda_1[q_1+\delta q_1+\alpha(\lambda_0+\lambda_1)+\delta\alpha-c]+\delta\lambda_2(q_1+\alpha-c)-F.$$

If the superior product of quality q_2^e is sold to everyone, social welfare becomes:

$$\begin{aligned} W_U &= \lambda_0[q_1+\delta q_2^e+\alpha(\lambda_0+\lambda_1)+\delta\alpha-c_u-\delta c_u]+\lambda_1[q_1+\delta q_2^e+\alpha(\lambda_0+\lambda_1)+\delta\alpha-c-\delta c_u]+ \\ &\quad +\delta\lambda_2(q_2^e+\alpha-c)-F-\delta F. \end{aligned}$$

Comparing the expressions above yields the socially optimal outcome:

Proposition 3 *It is socially efficient if (a) the product of quality q_1 is sold for two periods when assumptions A2 and A5 hold, (b) the product of quality q_2^e is introduced and purchased by the whole market if assumptions A2 and A6 hold.*

It is socially efficient if the good of quality q_1 is sold in the market for both periods when the net benefit from everyone purchasing it is smaller than the total investment and upgrading cost ($\Delta q^e < F+c_u(\lambda_0+\lambda_1)$). When the last inequality is reversed, social optimality is achieved when the superior product is introduced and purchased by the whole market.

Depending on the industry characteristics and the expected quality improvement, the market outcome may lead to socially undesirable results. More precisely, the next proposition highlights the potential inefficiency that may arise in markets that operate under a laissez faire Antitrust Law towards IPRs or not:

Proposition 4 *(a) If assumption A5 holds and unlike the market that operates under a laissez faire Competition Law towards IPRs, a regime of mandatory interoperability leads to the inefficient introduction of the product of quality q_2^e. (b) There is no inefficiency in the market where refusals to support interoperability are possible if the network parameter is bounded and smaller than the cost of upgrading ($\alpha < c_u$). (c) If network effects are strong*

($\alpha \geq c_u$), the market that operates under a laissez faire Competititon Law towards IPRs may lead to an inefficient technological slowdown when assumption A7 holds.

Let's first think of the case where network effects are not particularly strong and the upgrading cost is relatively high ($\alpha < c_u$). When the total cost (investment plus consumers' upgrading cost) is relatively high ($F \geq \Delta q^e - c_u(\lambda_0 + \lambda_1)$), social efficiency is obtained when the version of quality q_1 is retained in the market for both periods. At the same time, if the expected quality improvement is relatively small ($\Delta q^e < \alpha(\lambda_0 + \lambda_1)$), non-compatibility in a market where refusal to support compatibility is possible leads to the socially efficient use of the product of quality q_1 for both periods. On the other hand, in a regime of compulsory interoperability, the smaller firm introduces the product of quality q_2^e and the old and the new customers buy it while society would be better-off without it. Note that old consumers in the second period ($\lambda_0 + \lambda_1$) are not worse-off in the market where refusals to supply interoperability information do not violate Competition Law.

When network effects are greater than the learning cost ($\alpha \geq c_u$), the same inefficiency potentially arises in a market that mandates compatibility. Note that for relatively small values of the cost of development ((c) holds), it is socially efficient to introduce the product of quality q_2^e in the market in the second period and nevertheless, the market where firms can unilaterally refuse to supply interoperability information leads to technological slowdown by inefficiently withholding the product of quality q_2^e from the economy.

4 Applications/ Discussion/ Future Research

This paper serves as a new contribution in understanding how firms' decisions regarding compatibility relate to their incentives to invest into improving their durable, network goods. It is the first attempt to introduce a new framework in the literature by using a sequential game where the smaller firm can build on the dominant firm's existing knowledge. Our first key result is that a dominant firm may indeed support compatibility with its rival

and this happens when it anticipates a substantial quality improvement by the competitor. These expectations allow him to extract in the first period more of the higher total expected surplus that emerges when interoperability is present. On the other hand, the rival firm always supports compatibility because she can charge a higher price due to a larger network.

Moreover, an economy where refusal to supply interoperability information potentially violates the antitrust Law may lead to the inefficient introduction of a negligibly innovative product. We also find that when the network effects are present but not particularly strong, a market where compatibility is not mandatory converges to social efficiency. On top of that, existing customers are not worse-off in an economy where interoperability is not enforced by Law. When network effects are strong, the refusal to support connectivity may lead to the inefficient slowdown of technological progress. To the best of my knowledge, these are new results in the literature.

An important application captured by the model comes from the European Union case against Microsoft regarding its office suite highlighted earlier in the Introduction. Although Microsoft's compliance to compatibility was enforced by regulation, this mandate in favour of interoperability was unnecessary and may have been socially harmful. In particular, Microsoft Office 2007 was followed by Corel's WordPerfect Office suite in 2008 that introduced negligible quality improvements with a high upgrading cost. In anticipation of this, the technology giant decided not to support compatibility in the first place. As proposition 4(a) shows, society would be better-off without the new product and the market under a laissez faire Competition policy towards IPRs would lead to social efficiency assuming that network effects are relatively weak.

The policy implication of these findings is that the Antitrust Entities should investigate whether mandating compatibility may sometimes be socially unwelcome without benefiting consumers and instead markets that allow unilateral refusals to supply interoperability information possibly lead to efficient outcomes without necessarily hurting consumers' welfare. In an economy where network effects are present, this exercise is not trivial but one conclu-

sion is certain: if network effects are not too strong, an economy operating under a laissez faire Competition Law towards IPs generates social efficiency guaranteeing that existing consumers are not worse-off than in an economy under mandatory compatibility.

Nevertheless, there are a number of issues that are important and are not addressed in the paper. Firstly, a model that will test empirically our results could validate our predictions. Moreoever, further analysis could allow for interfirm payments for compatibility on a (F)RAND (fair, reasonable, non-discriminatroy) basis which is still not clearly defined in the European Union. In addition, an ambitious work would include the same interoperability/investment decisions from the rival firms in the presence of stochastic demand.

5 Appendix

5.1 Market outcome

5.1.1 Regime of Mandatory Interoperability

Period two New customers (λ_2) are assumed to coordinate, given prices, to what is best for all of them. Note that when interoperability is present, if customers buy the improved product, they join a network of size $\lambda_0 + \lambda_1 + \lambda_2$ independently of what others do, where without loss of generality, the size in the second period is normalized to unity. Thus, if they choose to buy q_2, their utility is $q_2 + \alpha - c - p_{22}$, where the first and the second subscripts in the price charged are related to the quality level of the product purchased and the type of customers buying the good, respectively. If they choose to buy q_1, the highest utility they can achieve is $q_1 + \alpha\lambda_2 + \alpha(\lambda_0 + \lambda_1)x_1 - c - p_{12}$ where x_1 is the old customers' fraction that

sticks to q_1. Thus, they will choose to buy q_2 if:

$$\begin{aligned} q_2 + \alpha - c - p_{22} &\geq q_1 + \alpha\lambda_2 + \alpha(\lambda_0 + \lambda_1)x_1 - c - p_{12} \text{ or} \\ p_{22} - p_{12} &\leq \Delta q + \alpha(\lambda_0 + \lambda_1)(1 - x_1) \end{aligned} \tag{1}$$

If the old customers $(\lambda_0 + \lambda_1)$ purchase q_2, their utility is $q_2 + \alpha - c_u - p_{21}$ independently of other customers' choices. Using the fact that they purchased the product of quality q_1 in the previous period, their utility if they stick to it will be $q_1 + \alpha\lambda_2 x_2 + \alpha(\lambda_0 + \lambda_1)x_1$, where x_1, x_2 are the fractions of $\lambda_0 + \lambda_1, \lambda_2$ customers that either stick or buy q_1 in the second period. Thus, they will purchase q_2 if:

$$\begin{aligned} q_2 + \alpha - c_u - p_{21} &\geq q_1 + \alpha\lambda_2 x_2 + \alpha(\lambda_0 + \lambda_1)x_1 \Leftrightarrow \\ p_{21} &\leq \Delta q + \alpha(\lambda_0 + \lambda_1)(1 - x_1) + \alpha\lambda_2(1 - x_2) - c_u \end{aligned} \tag{2}$$

Old customers are assumed to coordinate on the Pareto optimal outcome. That is, they upgrade to q_2 even if all other $\lambda_0 + \lambda_1$ stick to q_1 $(x_1 = 1)$ when:

$$p_{21} \leq \Delta q + \alpha\lambda_2(1 - x_2) - c_u.$$

Note that p_{21} is a decreasing function of the number of λ_2 that buy q_1. The competitors' choices are:

$$p_{22} = \Delta q + \alpha(\lambda_0 + \lambda_1)(1 - x_1),\ p_{12} = 0 \tag{1'}$$

and for this price choice, old customers know that the new comers will purchase the product q_2 $(x_2 = 0)$,

$$p_{21} \leq \Delta q + \alpha\lambda_2 - c_u \tag{2'}$$

Thus, old customers are willing to pay up to $\Delta q + \alpha\lambda_2 - c_u$ (we will see that in equilibrium, they will upgrade for free) and new customers pay $p_{22} = \Delta q + \alpha(\lambda_0 + \lambda_1)$ and get the new product.

Period one Let's first think of the new customers (λ_1). If they buy q_1, they expect that they will upgrade to q_2 in the following period. Thus, their total discounted expected utility is: $q_1 + \delta q_2^e + \alpha(\lambda_0 + \lambda_1) + \delta\alpha - c - \delta c_u - p_{11} - \delta p_{21}^e$, where p_{21}^e is the price they expect to pay in the second period.

If they buy the product of quality q_0, in period two, there are some possibilities: If they stick to q_0, their second period utility is: $q_0 + \alpha\lambda_1 x_1 + \alpha\lambda_0 x_0 + \alpha\lambda_2 x_2$, where x_1, x_0, x_2 are the fractions of λ_1, λ_0, λ_2 customers who stick or buy the product of quality q_0, respectively. If they buy q_1, their second period utility is $q_1 + \alpha\lambda_1 x_1^{'} + \alpha\lambda_2 x_2^{'} + \alpha\lambda_0 x_0^{'} - c_u - p_{11}$, where $x_0^{'}$, $x_1^{'}$, $x_2^{'}$ are the fractions of λ_0, λ_1, λ_2 consumers that buy or stick to q_1, respectively. If they buy q_2, their second period utility is $q_2 + \alpha - c_u - p_{21}$ independently of what other customers do. Under a reluctant rule, λ_1 customers will choose q_2 even if all other λ_1 customers buy q_1 or stick to q_0 if:

$$q_2 + \alpha - c_u - p_{21} \geq \max\{q_0 + \alpha\lambda_1 + \alpha\lambda_0 x_0 + \alpha\lambda_2 x_2,\ q_1 + \alpha\lambda_1 + \alpha\lambda_0 x_0^{'} + \alpha\lambda_2 x_2^{'} - c_u - p_{11}\}.$$

In any case, the dominant firm can charge a higher price to the λ_1 customers by selling the product of quality q_1.

Let's now turn our attention to the old consumers (λ_0). If they buy q_1, they expect that they will upgrade to q_2^e in the second period. Thus, their total discounted expected utility is $q_1 + \delta q_2^e + \alpha(\lambda_0 + \lambda_1) + \delta\alpha - c_u - \delta c_u - p_{10} - \delta p_{20}^e$. If they stick to q_0, in period two and similar to the previous analysis for the λ_1 customers, there are some possibilities: if they stick to q_0, their second period utility is: $q_0 + \alpha\lambda_0 x_0 + a\lambda_1 x_1 + \alpha\lambda_2 x_2$ where x_0, x_1, x_2 are the the different consumers' fractions that are expected to own the product of quality q_0 in the second period. If they buy q_1, their second period utility is $q_1 + \alpha\lambda_0 x_0^{'} + a\lambda_1 x_1^{'} + \alpha\lambda_2 x_2^{'} - c_u - p_{10}$, where

$x_0^{'}, x_1^{'}, x_2^{'}$ are the second period fractions of $\lambda_0, \lambda_1, \lambda_2$ that are expected to own q_1 in the second period. If they buy q_2, their utility is $q_2 + \alpha - c_u - p_{20}$. In a 'reluctant rule' where old customers make their purchasing decisions independently of what other old customers do, they will buy the superior product if:

$$q_2 + \alpha - c_u - p_{20}^{e'} \geq \max\{q_1 + \alpha\lambda_0 + a\lambda_1 x_1^{'} + \alpha\lambda_2 x_2^{'} - c_u - p_{10}^{e'},\ q_0 + \alpha\lambda_0 + \alpha\lambda_1 x_1 + \alpha\lambda_2 x_2\}.$$

So, if they stick to q_0 in the first period, their total expected discounted utility is $q_0 + \delta q_2^e + a\lambda_0 x_0^{''} + \alpha\lambda_1 x_1^{''} + \delta\alpha - \delta c_u - \delta p_{20}^{e\prime}$ where $p_{20}^{e'} = q_2^e - q_1 + \alpha\lambda_2(1 - x_2^{'}) + \alpha\lambda_1(1 - x_1^{'})$. Thus, the above expression reads: $q_0 + \delta q_1 + \alpha\lambda_0 x_0^{''} + a\lambda_1 x_1^{''} + \delta\alpha - \delta c_u - \delta\alpha\lambda_2(1 - x_2^{'}) - \delta\alpha\lambda_1(1 - x_1^{'})$. So, if old customers use a 'reluctant rule', they will prefer to buy q_1 in the first period if:

$$q_1 + \delta q_2^e + \alpha(\lambda_0 + \lambda_1) + \delta\alpha - c_u - \delta c_u - p_{10} - \delta p_{20}^e \geq$$

$$\geq q_0 + \delta q_1 + \alpha\lambda_0 + a\lambda_1 x_1^{''} + \delta\alpha - \delta c_u - \delta\alpha\lambda_2(1 - x_2^{'}) - \delta\alpha\lambda_1(1 - x_1^{'})$$

or equivalently:

$$p_{10} + \delta p_{20}^e \leq \Delta q + \delta\Delta q^e + \alpha\lambda_1(1 - x_1^{''}) + \delta\alpha\lambda_2(1 - x_2^{'}) + \delta\alpha\lambda_1(1 - x_1^{'}) - c_u + \delta c_u.$$

The price to the λ_0 customers is a decreasing function of the number of the new customers who buy the product of quality q_0 ($x_1^{''}$). Thus, the optimal dominant firm's choice is to stop selling the product of quality q_0 in the first period. Thus, the first period optimal pricing decisions are given by the expressions:

$$\begin{aligned} p_{11} + \delta p_{21}^e &= q_1 + \delta q_2^e + \alpha(\lambda_0 + \lambda_1) + \delta\alpha - c - \delta c_u, \\ p_{10} + \delta p_{20}^e &= \Delta q + \delta\Delta q^e + \alpha\lambda_1 + \delta\alpha\lambda_2(1 - x_2^{'}) + \delta\alpha\lambda_1(1 - x_1^{'}) - c_u. \end{aligned}$$

We observe that the expected payment that new and old customers are willing to pay in the

first period is fixed. So, the dominant firm's optimal choice is to set:

$$p_{11} = q_1 + \delta q_2^e + \alpha(\lambda_0 + \lambda_1) + \delta\alpha - c - \delta c_u \quad (3)$$

$$p_{10} = \Delta q + \delta \Delta q^e + \alpha\lambda_1 + \delta\alpha\lambda_2(1 - x_2^{'}) + \delta\alpha\lambda_1(1 - x_1^{'}) - c_u \quad (4)$$

Thus, in the second period, the smaller firm will be induced to upgrade all old customers $(\lambda_0 + \lambda_1)$ for free and this fact will not deter her from investing (note we have assumed a relatively small cost of development).

Note that in the second period (1)' and (2)' give the equilibrium prices:

$$p_{22} = \Delta q^e + \alpha(\lambda_0 + \lambda_1),\ p_{12} = 0,\ p_{21} = 0$$

and λ_2 buy the new product q_2^e while old customers upgrade for free. From (3) and (4), we also get the equilibrium first period prices:

$$\begin{aligned} p_{11} &= q_1 + \delta q_2^e + \alpha(\lambda_0 + \lambda_1) + \delta\alpha - c - \delta c_u, \\ p_{10} &= \Delta q + \delta \Delta q^e + \alpha\lambda_1 + \delta\alpha\lambda_2 + \delta\alpha\lambda_1 - c_u \end{aligned}$$

where in (4): $x_2^{'} = x_1^{'} = 0$ (the fractions of customers who are expected to buy or stick to q_1 in the second period given p_{11} is observed by both the old and the new customers and the expectations about the second period play).

5.1.2 Regime of no Interoperability

Period two Let's first think about the new customers (λ_2). If they all buy q_2, their utility is $q_2 + \alpha\lambda_2 + \alpha\lambda_1(1 - x_1) + \alpha\lambda_0(1 - x_0) - c - p_{22}$ and if they all buy q_1, their utility is $q_1 + \alpha\lambda_2 + \alpha(\lambda_1 + \lambda_0)x_1 - c - p_{12}$, where x_1, x_2 are the old and new customers' fractions that

stick to q_1. Thus, λ_2 customers will buy q_2 if:

$$\begin{aligned} q_2 + \alpha\lambda_1(1-x_1) + \alpha\lambda_0(1-x_0) - c - p_{22} &\geq q_1 + \alpha\lambda_1 x_1 + \alpha\lambda_0 x_0 - c - p_{12} \Leftrightarrow \\ p_{22} - p_{12} &\leq \Delta q + \alpha(\lambda_0+\lambda_1)(1-2x_1). \end{aligned} \tag{5}$$

Old customers' $(\lambda_0 + \lambda_1)$ utility if they purchase q_2 is $q_2 + \alpha\lambda_0(1-x_0) + \alpha\lambda_1(1-x_1) + \alpha\lambda_2(1-x_2) - c_u - p_{21}$ while if they stick to q_1 their utility is $q_1 + \alpha\lambda_2 x_2 + \alpha\lambda_1 x_1 + \alpha\lambda_0 x_0$, where x_0, x_1, x_2 are the old and new customers' fractions that stick or buy q_1 in the second period. In a reluctant rule, old customers will choose to buy q_2 even if all other old customers stick or buy q_1 $(x_1 = x_0 = 1)$ when:

$$\Delta q + \alpha\lambda_2(1-2x_2) - \alpha(\lambda_0+\lambda_1) - c_u \geq p_{21}.$$

Our initial assumption rules out the possibility of the old customers' upgrading in the second period. Thus, the new potential customers know that $x_1 = 0$ in (5), and this means that the equilibrium depends on whether quality differential in the second period is relatively high $[\Delta q \geq \alpha(\lambda_0 + \lambda_1)]$ or not. If it is indeed the case that the quality differential is not negligible, the second period equilibrium prices set to the new customers are given by (5):

$$p_{22} = \Delta q - \alpha(\lambda_0+\lambda_1),\ p_{12} = 0$$

who in equilibrium, choose to buy the new product q_2^e. If not, the rival is deterred to invest.

Period one

Case 1: $\Delta q^e < \alpha(\lambda_0 + \lambda_1)$. If λ_1 customers buy the good of quality q_1 in the first period, their total expected discounted utility is $q_1 + \delta q_1 + \alpha(\lambda_0+\lambda_1) + \delta\alpha - c - p_{11.}$ If they

buy q_0, there are some possibilities in the future: if they stick to q_0, their second period utility will be $q_0 + \alpha\lambda_0 x_0 + \alpha\lambda_1 x_1 + \alpha\lambda_2 x_2$, where x_0, x_1, x_2 are the fractions of $\lambda_0, \lambda_1, \lambda_2$ who own the initial version, respectively while if they buy q_1, their utility is $q_1 + \alpha - c_u - p_{11'}$ independently of what other customers do. Thus, if they use a reluctant rule, λ_1 customers will buy the product of quality q_1 even if all other λ_1 stick to q_0 if:

$$q_1 + \alpha - c_u - p_{11}^{'} \geq q_0 + \alpha\lambda_1 + \alpha\lambda_0 x_0 + \alpha\lambda_2 x_2.$$

So, their total expected discounted utility if they buy q_0 in the first period is $q_0 + \delta q_1 + \alpha\lambda_0 x_0 + \alpha\lambda_1 x_1 + \delta\alpha - c - \delta c_u - p_{01} - \delta p_{11}^{'}$. It is clear that the dominant firm can charge a higher price by selling the product of quality q_1 to the new customers rather than the product of quality q_0.

Let's now turn our attention to the old consumers in the first period (λ_0). If they buy the product of quality q_1, their total expected discounted utility is $q_1 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta\alpha - c_u - p_{10}$. If they stick to q_0, there are some possibilities in the following period: if they keep q_0, their second period utility is $q_0 + \alpha\lambda_0 x_0^{'} + \alpha\lambda_1 x_1^{'} + \alpha\lambda_2 x_2^{'}$. If they buy q_1, their utility will be $q_1 + \alpha - c_u - p_{10}^e$. Thus, they will buy the higher quality product in the second period when they use the reluctant rule if:

$$\begin{aligned} q_1 + \alpha - c_u - p_{10}^e &\geq q_0 + \alpha\lambda_0 + \alpha\lambda_1 x_1^{'} + \alpha\lambda_2 x_2^{'} \Leftrightarrow \\ p_{10}^e &\leq \Delta q + \alpha\lambda_1(1 - x_1^{'}) + \alpha\lambda_2(1 - x_2^{'}) - c_u. \end{aligned}$$

Recalling that $\Delta q > c_u$, the price expected to be set by the dominant firm in the second period is $p_{10}^e = \Delta q + \alpha\lambda_1(1 - x_1^{'}) + \alpha\lambda_2(1 - x_2^{'}) - c_u$ and λ_0 customers buy the product of quality q_1. Thus, their expected total discounted utility if they stick to the initial version q_0 is $q_0 + \delta q_1 + \alpha\lambda_0 x_0 + \alpha\lambda_1 x_1 + \delta\alpha - \delta c_u - \delta p_{10}^e$. Since old customers decide to upgrade to q_1 even if all other old consumers stick to q_0, old customers in the first period purchase the

product of quality q_1 if:

$$\begin{aligned} q_1 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta\alpha - c_u - p_{10} &\geq q_0 + \delta q_1 + \alpha\lambda_0 + \alpha\lambda_1 x_1 + \delta\alpha - \delta c_u - \delta p^e_{10} \Leftrightarrow \\ p_{10} &\leq \Delta q + \alpha\lambda_1(1 - x_1) - c_u + \delta c_u + \delta p^e_{10}. \end{aligned}$$

Notice that since the dominant firm's profits are a decreasing function of the number of λ_1 customers that buy q_0 in the first period (x_1), the optimal dominant firm's choice is to stop selling the initial version in the first period (thus $x_1 = 0$ in the last inequality above). Thus, the equilibrium first and second period prices are given by the expressions:

$$\begin{aligned} p_{11} &= q_1 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta\alpha - c, \\ p_{10} &= \Delta q + \alpha\lambda_1 - c_u + \delta c_u + \delta p^e_{10}, \text{ where} \\ p^e_{10} &= \Delta q + \alpha\lambda_1 + \alpha\lambda_2 - c_u, \\ p_{12} &= q_1 + \alpha - c. \end{aligned}$$

Case 2: $\Delta q^e \geq \alpha(\lambda_0 + \lambda_1)$. Let's first think of the new customers in the first period (λ_1). If they buy the product of quality q_1, their expected utility is $q_1 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta\alpha(\lambda_0 + \lambda_1) - c - p_{11}$ because they expect not to upgrade to q^e_2 in the following period. If they buy q_0, there are some possibilities in the second period: If they stick to q_0, their utility is $q_0 + \alpha\lambda_0 x_0 + \alpha\lambda_1 x_1 + \alpha\lambda_2 x_2$. If they buy q_1, their second period utility is $q_1 + \alpha\lambda_0 x_{0'} + \alpha\lambda_1 x_1^{'} + \alpha\lambda_2 x_2^{'} - c_u - p_{11}$ while if they buy q_2, their utility is $q_2 + \alpha\lambda_0 x_0^{''} + \alpha\lambda_1 x_1^{''} + \alpha\lambda_2 x_2^{''} - c_u - p_{21}$. It is clear that the dominant firm can charge more the new first period customers by selling the product of quality q_1.

Let's now turn our attention to the old customers in the first period (λ_0). If they upgrade to q_1, their total expected discounted utility is $q_1 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta\alpha(\lambda_0 + \lambda_1) - c_u - p_{10}$ where they anticipate that they will not buy the superior product of quality q_2 in the second period and the new second period customers are expected to buy the q^e_2. If they keep

q_0, there are some possibilities in the second period: if they stick to the initial version, their second period utility is $q_0 + \alpha\lambda_0 x_0 + \alpha\lambda_1 x_1 + \alpha\lambda_2 x_2$. If they buy q_1, their utility is $q_1 + \alpha\lambda_0 x_0^{'} + \alpha\lambda_1 x_1^{'} + \alpha\lambda_2 x_2^{'} - c_u - p_{10}$ whereas if they choose to buy the product of quality q_2, their utility is $q_2 + \alpha\lambda_0 x_0^{''} + \alpha\lambda_1 x_1^{''} + \alpha\lambda_2 x_2^{''} - c_u - p_{20}$. They will buy q_2 in the second period even if all λ_0 buy q_1 (both these choices strictly dominate all λ_0 keeping q_0 in the second period) if:

$$q_2 + \alpha\lambda_0 + \alpha\lambda_1 x_1^{''} + \alpha\lambda_2 x_2^{''} - c_u - p_{20} \geq$$

$$\geq \max\{q_1 + \alpha\lambda_0 + \alpha\lambda_1 x_1^{'} + \alpha\lambda_2 x_2^{'} - c_u - p_{10},\ q_0 + \alpha\lambda_0 x_0 + \alpha\lambda_1 x_1 + \alpha\lambda_2 x_2\}$$

and thus

$$p_{20} = \Delta q^e - \alpha\lambda_1(x_1^{''} - x_1^{'}) + \alpha\lambda_2(x_2^{''} - x_2^{'}),\ p_{10} = 0.$$

Thus, their total expected discounted utility if they buy q_0 is $q_0 + \delta q_2^e + \alpha\lambda_0 x_0^{'''} + \alpha\lambda_1 x_1^{'''} + \delta\alpha\lambda_0 x_0^{''''} + \delta\alpha\lambda_1 x_1^{''''} + \delta\alpha\lambda_2 x_2^{''''} - \delta c_u - \delta p_{20}$ where p_{20} is given above. These consumers will buy q_1 in the first period even if all others choose q_0 if:

$$q_1 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta\alpha(\lambda_0 + \lambda_1) - c_u - p_{10} \geq$$

$$\geq q_0 + \delta q_2^e + \alpha\lambda_0 + \alpha\lambda_1 x_1^{'''} + \delta\alpha\lambda_0 x_0^{''''} + \delta\alpha\lambda_1 x_1^{''''} + \delta\alpha\lambda_2 x_2^{''''} - \delta c_u - \delta p_{20} \tag{6}$$

Since p_{10} is a decreasing function of the number of λ_1 customers who buy q_0 in the first period, the dominant firm's optimal choice is to stop selling q_0 in the first period (thus, $x_1^{'''} = 0$ in the inequality above). This means that the equilibrium price set to λ_1 customers is:

$$p_{11} = q_1 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta\alpha(\lambda_0 + \lambda_1) - c.$$

Old first period customers observe this price and know that λ_1 customers buy the product

of quality q_1 in the first period. Moreover,

$$p_{20} = \Delta q^e - \alpha\lambda_1 + \alpha\lambda_2$$

because old customers expect the new first period customers (λ_1) to buy q_1 in the first period and λ_2 customers to buy q_2^e in the second period. Note that in the alternative scenario that old customers stick to q_0, they expect p_{20} in the second period as well as for this p_{20} the old (λ_0) to buy q_2 just like the λ_2 (λ_1 are not expected to upgrade to q_2) and thus, $x_0'''' = 1$, $x_1'''' = 0$ and $x_2'''' = 1$. (6) gives the equilibrium price set to the old first period customers:

$$p_{10} = \Delta q + \alpha\lambda_1 - c_u + \delta c_u,$$

To recap, in this case, the equilibrium prices charged as well as the profits for both competitors are given by the expressions:

$$\begin{aligned} p_{11} &= q_1 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta\alpha(\lambda_0 + \lambda_1) - c. \\ p_{10} &= \Delta q + \alpha\lambda_1 - c_u + \delta c_u, \\ p_{22} &= \Delta q^e - \alpha(\lambda_0 + \lambda_1),\ p_{12} = 0. \end{aligned}$$

The dominant firm compares its expected profit under the two regimes and decides whether to support compatibility or not.

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