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

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Abstract

This article investigates dominant firms' approach towards the compatibility of their durable network goods with that of a future, innovative rival in the presence of overlapping generations of forward-looking consumers and the welfare effects from dominant firms' refusals to support compatibility. I consider sequential, substitutable product innovations, where a rival can build on a dominant firm's existing knowledge. For moderately innovative future products, the market leader supports compatibility because strategic pricing allows him to extract more of the higher total surplus that emerges when compatibility is present. Incompatible networks increase consumer surplus and there is no market failure when network effects are weak.

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1 Introduction

Should dominant firms with durable network goods like markets for the applications in the software market industry have the obligation to provide technical compatibility information to direct competitors? This fundamental question lies at the intersection of competition and intellectual property law and different countries give different answers.

In the European Union, market leaders must provide interoperability[3] information to rivals and failure to do so is a potential violation of Article 102 (ex article 82) of the European competition law.[4] In a nutshell, a refusal to license Intellectual Property may, in itself, constitute a breach of Article 102 if all the following conditions are met: a) access is indispensable for carrying on a particular business, b) it results in the elimination of competition on a secondary market and c) it may lead to consumer harm.[5] A famous example comes from the 2008 European Commission case against Microsoft, which was related to the firm's refusal to provide competitors technical information about its Office suite so that they could craft interoperable software.[6] The case followed a complaint[7] 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.[8]

In contrast, in the United States, a more laissez faire competition law is favoured. For example, 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".[9] Indeed, the U.S antitrust authorities conclude that "antitrust liability for mere unilateral, unconditional

[3] We will use the terms interoperability and compatibility interchangeably throughout the paper.
[4] See http://ec.europa.eu/competition/antitrust/legislation/handbook_vol_1_en.pdf
[5] See http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52009XC0224(01)&from=EN
[6] See http://europa.eu/rapid/press-release_MEMO-08-19_en.htm

[7] See www.techhive.com/article/124813/article.html
[8] See http://europa.eu/rapid/press-release_IP-09-1941_en.htm?locale=en
[9] See http://uk.reuters.com/article/2007/09/17/microsoft-eu-usa-idUKN1734095320070917

refusal to license patents will not play a meaningful part in the interface between patent rights and antitrust protections".[10]

In this article I investigate dominant firms' approaches towards interoperability and the welfare effects of refusals to supply interoperability that may occur in a laissez faire economy. More precisely, my work provides answers to the following questions: When do market leaders block interoperability with a rival future innovator and under what conditions would they support compatibility? If there is incompatibility, does this de-facto mean that it is socially undesirable? Could a laissez faire market converge to interoperability when it is socially efficient? Are consumers better-off in an economy that mandates compatibility?

To answer these questions, I built a sequential game in which an innovative rival initially decides whether to invest in product quality. The rival's choice depends on the importance of her idea and the dominant firm's future support or refusal to supply interoperability information due to the leader's large installed base of consumers. This model fits a common pattern in durable, technology goods markets, where a smaller rival may have valuable ideas emerging as follow-on, non-drastic substitutable innovations, after the dominant firm's invention hits the market in a Schumpeterian scenario of creative destruction. My analysis shows that given modest structure on consumer preferences, the market leader would choose to support compatibility for moderately innovative rival's future products. This reflects that strategic pricing would allow him to extract more of the higher future surplus in the present market independently of customers' (un)willingness to postpone purchasing decisions and the rival's power to exercise price discrimination. When incompatible networks arise, consumer surplus increases relative to the scenario of mandatory compatibility due to more fierce competitive forces that reduce prices. I also demonstrate that mandatory compatibility does not de-facto maximise social welfare, while there is no market failure when network effects are weak. Our conclusions cast doubts as to whether mandatory interoperability, while trying to support competition, allow technological advancement and protect consumers from abusive

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

behaviour, may actually distort the market and lead to both socially undesirable results and customers' harm.

This article is organized as follows: I next discuss related literature. Section 2 presents the model. Section 3 considers the case where the anticipated second period quality improvements are moderately large. I characterize equilibrium outcomes when compatibility is mandatory and when the economy operates under a laissez faire competition law toward Intellectual Property Rights holders. I then analyze the problem of a social planner who wishes to maximise social surplus and I contrast equilibrium outcomes with the social optimum. I also look at the effects of dominant firms' refusals to supply compatibility on consumer surplus. Section 4 discusses applications and concludes.

Related Literature

This work contributes to the literature regarding firms' incentives toward compatibility with their competitors when network effects are present. In a seminal article, Katz and Shapiro (1985) show that firms with a larger installed base prefer to be incompatible with their rivals. In the same vein, Cremer, Rey and Tirole (2000) analyze 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 not support connectivity with firms that are themselves compatible when its market share exceeds fifty percent, or the potential to add consumers falls. Similar results appear in Chen, Doraszelski and Harrington (2009), 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. If, instead, firms have similar installed bases, they make their products interoperable to expand the market. Viecens (2009) distinguishes 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: 1) compatibility of the complementary good, which she calls compatibility in applications, 2) inter-network compatibility with direct network externalities. She finds that the dominant firm never promotes compatibility in applications but both firms find inter-network compatibility profitable. In contrast to this literature, I focus on durable goods with direct network effects. Both durability and network externalities are important features of most software products that are at the heart of this compatibility question. Contrary to the literature, I consider improvements in product quality and find that the dominant firm may support compatibility with its rival when the quality improvement introduced by the smaller firm is moderately large.

Economides (2006) argues that it is socially efficient to move toward compatibility. Similarly, in Katz and Shapiro (1985), interoperability would raise consumer 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. I find that interoperability could lead to losses both in consumer surplus and social welfare because unlike a market that operates under a laissez faire competition law, compulsory compatibility may result in higher prices and in the inefficient introduction of a higher quality product, when the quality improvement is small relative to the network externalities and the cost of its adoption, in which case society would be better-off without it.

A second related strand of literature explores firms' incentives to upgrade durable, network goods and how these decisions affect social welfare. In a monopolistic environment, Ellison and Fudenberg (2000) show that upgrades may occur too frequently due to a firm's inability to commit to whether it will upgrade in the future or not. The present paper indicates that in a market that operates under a laissez faire competition law, the social and private incentives for producing better products are aligned when network effects are weak.

In the literature on sequential innovation, Scotchmer (1991, 1996), Scotchmer and Green (1996) and others 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 than when innovation is concentrated in one firm. I am mainly interested in the interplay between Intellectual Property Rights protection and firms' behaviour towards compatibility. In contrast to these articles, I find that the first innovator will voluntarily offer compatibility to rivals because strategic pricing enables him to absorb more of the expected future profit when he anticipates a moderately large improvement from the second innovator.

2 The Model

My objective is to provide insights into how dominant firms' short-run compatibility and pricing decisions regarding their durable network goods relate to homogeneous, forward-looking consumers, and how these anticipated compatibility choices affect an innovative rival's investment in R&D. The industry I have in mind is the market for computer software applications highlighted in the introduction.

Supply

In the two-date model, the sequence of events in the supply side is as follows (see figure 1): initially, the dominant firm has an installed base λ_0 of consumers and is marketing its product, which improves the level of quality from the previously sold version of quality q_0 to a higher level q_1.[11] The upgraded version of quality q_1 is backward compatible, allowing its purchasers to interact with the users of the old version of quality q_0. In contrast, forward incompatibility prevents users of the initial version from editing and saving documents that are created with the upgrade.[12]

At the beginning of date t=1, a risk neutral rival can choose to incur a fixed cost F

[11] I follow Ellison and Fudenberg (2000) who also assume quality as a positive, real number.

[12] See Ellison and Fudenberg (2000) for a paper with backward compatibility but forward incompatibility.

to create a future substitute product of quality q_2, which is distributed according to the continuous cumulative distribution function $\Phi(.)$. The fact that the rival is the only firm that can build on the initial incumbent's improved product of quality q_1 may raise the question: why is it not the dominant firm that is the further innovator?[13] After all, it knows its products and it also knows that its improved good of quality q_1 could be improved further. The assumption is designed to capture the widely observed scenario in the high-tech and software industry that small rivals often have better ideas than the initially dominant firm. Thus, the model does not necessarily assume that the dominant firm has no further ideas; rather, it captures the fact that a competitor may have a better, future idea.

At the end of date t=1, the quality of the rival's product q_2 is publically known.[14] The market leader sets the price(s) for his product(s) and decides whether to support compatibility of his version(s) with the rival's product of quality q_2, which is a binary decision. Following Malueg and Schwartz (2006), I assume that compatibility requires both parties' consent and cannot be achieved unilaterally using converters or adapters. In addition, in order to avoid potentially collusive behaviour, licensing of Intellectual Property is free.[15]

If the dominant firm chooses to be compatible, purchasers of a product of quality q_2 belong to a network of maximum size due to backward compatibility. In contrast, users of the product of quality q_1 cannot interact with the purchasers of the new version unless they buy the superior product.

Note that the dominant firm's future potential refusal to support compatibility does not, per se, hinder innovation, as there is an alternative route that allows the rival to innovate without using the dominant firm's network of existing customers. This assumption accords with the Microsoft Office case highlighted in the introduction: Microsoft's refusal to offer compatibility did not, per se, prevent rivals from innovating as they could use the Open Document Format, which could allow product innovation.

[13] In a related paper, I allow both firms to be future potential innovators.
[14] Current work investigates the role of private information in this setting.
[15] See Malueg and Schwartz (2006).

At date t=2, both profit maximising firms simultaneously set prices. Consistent with software applications, I assume that the marginal cost of production is zero for all versions. Note that I assume that both firms have the power to exercise price discrimination between the different consumer groups.

Demand

Consumers are identical and have a per period unitary demand. Initially, there is a mass λ_0 of customers in the economy who have purchased the dominant firm's product of quality q_0 at a past date (t=0), and new customers arrive in flows of measure λ_t at dates t=1,2.

At the end of date t=1, a measure λ_1 of new customers observes the dominant firm's prices for its products of quality q_0 and q_1. Their utility is linear in income and partially dependent on direct network effects captured by a parameter α, while they incur a cost c to learn how to use a product. Thus, if they purchase the product of quality q_1 and because of its backward compatibility with the old version of quality q_0, they join a network of maximum size at date t=1 and their total discounted utility is $q_1 + \alpha(\lambda_0 + \lambda_1) - c - p_{11} + \delta V$, where $\lambda_0 + \lambda_1$ is the market size at t=1, p_{11} is the dominant firm's price and δ is the common discount factor for all the agents in the economy and thus, δV is their net discounted date t=2 utility.[16] If they buy the product of quality q_0 and because of its forward incompatibility with q_1, their utility is $q_0 + \alpha\lambda_0 x_0 + \alpha\lambda_1 x_1 - c - p_{01} + \delta V'$, where x_0, x_1 are the old and new customers' fractions that own q_0, respectively, and $\delta V'$ is their net discounted date t=2 utility. I analyze both the case that a measure λ_1 of new customers at t=1 cannot postpone their purchase, and where they are willing to wait. A measure λ_0 of old customers owns the product of quality q_0 and observes the market leader's upgrade price p_{10} for his product q_1. If a customer buys it, her total discounted benefit is $q_1 + \alpha(\lambda_0 + \lambda_1) - c_u - p_{10} + \delta V$, where c_u is the additional adoption cost she needs to incur ($c_u < c$), while if she sticks to q_0, her total discounted utility is $q_0 + \alpha\lambda_0 x_0 + \alpha\lambda_1 x_1 + \delta V'$. A date t=1 customer's overall benefit

[16] Note that the utility function may not be necessarily linear in income (any monotonic transformation would suffice).

depends on her forecast of how other customers make purchase decisions.

At date t=2, a measure $\lambda_0 + \lambda_1$ of old consumers observes the competitors' prices. If a customer that belongs to this group keeps the product of quality q_1[17] and because of its forward incompatibility with the new product of quality q_2, her utility is $V = q_1 + \alpha\lambda_2 x_2 + \alpha(\lambda_0+\lambda_1)x_1^{'}$, where x_2 and $x_1^{'}$ are the new and old date t=2 customers' fractions that also own q_1 at date t=2, respectively. If she purchases the rival's product of quality q_2 in the presence of compatibility, her net utility is $V = q_2 + \alpha - c_u - p_{21}$ due to backward compatibility of the product of quality q_2, after normalizing the date t=2 market size to unity. If compatibility is not supported, her utility by purchasing q_2 is $q_2 + \alpha\lambda_2(1-x_2) + \alpha(\lambda_0+\lambda_1)(1-x_1^{'}) - c_u - p_{21}^{'}$, where $1-x_2$ and $1-x_1^{'}$ are the new and old date t=2 customers' fractions that also purchase q_2 at date t=2, respectively. Although old consumers' coordination problem has multiple equilibria, I assume that they coordinate on the Pareto optimum and in particular, the measure λ_0 of old consumers at date t=1 coordinates on the global Pareto optimum. A measure λ_2 of new consumers also observes the competitors' prices. If they purchase the dominant firm's product of quality q_1, their utility is $q_1 + \alpha\lambda_2 x_2 + \alpha(\lambda_0 + \lambda_1)x_1^{'} - c - p_{12}$, where x_2 and $x_1^{'}$ are the new (λ_2) and old ($\lambda_0 + \lambda_1$) date 2 customers' fractions that also own q_1, respectively. When the dominant firm does not support compatibility with the rival's new product of quality q_2, their benefit from getting the product of quality q_2 is $q_2 + \alpha\lambda_2(1 - x_2) + \alpha(\lambda_0 + \lambda_1)(1 - x_1^{'}) - c - p_{22}^{'}$, as they form a network only with those consumers who also own it. If they buy the product of quality q_2 and compatibility is present, their utility is $q_2 + \alpha - c - p_{22}$ due to backward compatibility of the product of quality q_2 with the dominant firm's product of quality q_1. New customers' purchasing decision resembles a coordination game and following the literature, I assume that they behave as a single player.[18] All consumers make their purchasing decisions simultaneously and prefer a new product rather than an older version when they gain the same net utility from each of these

[17] We will see in the analysis that the dominant firm's optimal choice at date t=1 is to induce all consumers to purchase its product of quality q_1 at t=1.

[18] See Ellison and Fudenberg (2000).

two choices.

3 Moderate quality improvements

Market outcome

We solve for equilibrium outcomes when compatibility is mandatory, followed by a market operating under a laissez faire competition law. Our benchmark case considers that new date t=1 customers cannot postpone their purchase and the rival firm has the power to price discriminate.

Mandatory compatibility

Date t=2 If new customers buy the product of quality q_2, their utility is $q_2 + \alpha - c - p_{22}$, where the first and second subscripts in the price p_{22} index the product quality and customers' type, respectively. If they buy q_1, their utility, given the dominant firm's price p_{12} is $q_1 + \alpha\lambda_2 x_2 + \alpha(\lambda_0 + \lambda_1)x_1 - c - p_{12}$, where x_1, x_2 are the old and new date t=2 customers' fractions that use q_1, respectively.[19] New customers behave as a single player and thus, they will choose to buy q_2 if:

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

where $\Delta q' = q_2 - q_1$ denotes the quality improvement from purchasing the product of quality q_2 instead of q_1.

Let's now turn our attention to the measure $\lambda_0 + \lambda_1$ of old date t=2 customers. An old customer's utility from purchasing q_2, given the rival's price p_{21}, is $q_2 + \alpha - c_u - p_{21}$. If she sticks to q_1, her utility is $q_1 + \alpha\lambda_2 x_2 + \alpha(\lambda_0 + \lambda_1)x_1$, where x_1, x_2 are the $\lambda_0 + \lambda_1$ and λ_2 customers' fractions that either stick or buy q_1 at date t=2, respectively. Thus, she purchases

[19] It will become apparent in the first period analysis that the old date t=2 customers $(\lambda_0 + \lambda_1)$ purchased q_1 in the previous period.

q_2 even if all other $\lambda_0 + \lambda_1$ stick to q_1 when:

$$p_{21} \leq \Delta q' + \alpha\lambda_2(1 - x_2) - c_u, \tag{2}$$

where we assume:

Assumption 1 (A1): $\Delta q' + \alpha\lambda_2 - c_u \geq 0$.

This assumption says that at date t=2, the measure $\lambda_0 + \lambda_1$ of old date t=1 consumers benefits from purchasing the new product of quality q_2, allowing us to focus on the interplay between the extent of network externalities and the magnitude of the quality improvement from the introduction of the product of quality q_2.

Thus, the date t=2 equilibrium prices are:

$$p_{22} = \Delta q' + \alpha(\lambda_0 + \lambda_1), \; p_{21} = \Delta q' + \alpha\lambda_2 - c_u. \tag{2'}$$

Date t=1 If new date t=1 customers (λ_1) buy version q_1, their total net discounted utility, given the price set by the dominant firm p_{11} is $q_1 + \delta q_2 + \alpha(\lambda_0 + \lambda_1) + \delta\alpha - c - \delta c_u - p_{11} - \delta p_{21}$, where p_{21} is the price they will pay to buy q_2 at date t=2. Thus, the dominant firm's optimal price set to these customers is:

$$p_{11} = q_1 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta\alpha(\lambda_0 + \lambda_1) - c. \tag{3}$$

Note that due to the fact that the dominant firm's maximum price to these customers by selling the product of quality q_0 is strictly smaller than p_{11}, its optimal choice is to stop selling the product of quality q_0 at date t=1 because otherwise, its profits may be cannibalized from the presence of its two competing products.

Let's now think of the measure λ_0 of old date t=1 customers. An old consumer's total discounted utility from upgrading to q_1, given the price p_{10}, is $q_1 + \delta q_2 + \alpha(\lambda_0 + \lambda_1) + \delta\alpha - c_u - \delta c_u - p_{10} - \delta p_{21}$, where p_{21} is the price she will pay in the second period to buy the superior product q_2. If this consumer sticks to q_0, she knows that both the measures λ_2 and λ_1 of new date t=2 and new date t=1 consumers, respectively, will purchase the product of quality q_2 at date t=2. Thus, her total discounted expected utility from sticking to q_0 is $q_0 + \delta q_2 + a\lambda_0 x_0^{''} + \delta\alpha - \delta c_u - \delta p_{20}^{e\prime}$, where $p_{20}^{e\prime} = q_2 - q_1 + \alpha\lambda_1 + \alpha\lambda_2 + a\lambda_0(1 - x_0)$ is the price she expects to pay in order to get q_2 at date t=2 and $x_0^{''}$ is the λ_0 customers' fraction that sticks to q_0 at date t=1, while x_0 is the λ_0 consumers' fraction that purchases q_1 instead of q_2 at date t=2. This consumer purchases the product of quality q_1 even if all the other old date t=1 customers currently stick to q_0 ($x_0^{''} = 1$), while she also uses the same decision rule whenever she makes potential purchasing decisions ($x_0 = 1$) when her total discounted payoff from purchasing q_1 is at least equal to her total discounted payoff from sticking to q_0:

$$q_1 + \delta q_2 + \alpha(\lambda_0 + \lambda_1) + \delta\alpha - c_u - \delta c_u - p_{10} - \delta p_{21} \geq q_0 + \delta q_2 + a\lambda_0 + \delta\alpha - \delta c_u - \delta p_{20}^{e\prime},$$

or equivalently, the maximum date t=1 price for the product of quality q_1 is:

$$p_{10} = \Delta q + \alpha\lambda_1 + \delta\alpha\lambda_1 - c_u(1 - \delta), \tag{4}$$

where $\Delta q = q_1 - q_0$ is the quality improvement from the introduction of the product of quality q_1.

The following proposition summarizes the equilibrium outcome in an economy where compatibility is mandatory and it holds independently of new first period customers' willingness to wait:

Proposition 1 *The dominant firm's optimal choice is to stop selling the product of quality q_0 at date t=1. The product of quality q_2 is always sold at date t=2 and the whole market purchases it.*

Laissez faire Competition Law

We will solve for equilibrium outcomes when the economy operates under a laissez faire competition law after discussing firms' and customers' optimal choices when there is incompatibility in the market.

Date t=2 Incompatibility allows consumers to be compatible only with those who own the same product. If all new customers (λ_2) buy the product of quality q_2, their utility is $q_2 + \alpha\lambda_2 + \alpha(\lambda_0 + \lambda_1)(1 - x_1) - c - p_{22}$ and if they all buy q_1, their utility is $q_1 + \alpha\lambda_2 + \alpha(\lambda_1 + \lambda_0)x_1 - p_{12}$, where x_1 is the old date t=2 customers' fraction that sticks to q_1.[20] Thus, λ_2 customers buy q_2 if:

$$p_{22} - p_{12} < \Delta q^{'} + \alpha(\lambda_0 + \lambda_1)(1 - 2x_1). \tag{5}$$

If an old customer purchases q_2, her utility is $q_2 + \alpha(\lambda_0 + \lambda_1)(1 - x_1) + \alpha\lambda_2(1 - x_2) - c_u - p_{21}$, while if she sticks to q_1, her utility is $q_1 + \alpha\lambda_2 x_2 + \alpha(\lambda_1 + \lambda_0)x_1$, where x_1, x_2 are the old and new date t=2 customers' fractions that stick or buy q_1, respectively. Thus, she will choose to buy q_2 even if all other old customers stick or buy q_1 ($x_1 = 1$) when:

$$p_{21} \leq \Delta q^{'} + \alpha\lambda_2(1 - 2x_2) - \alpha(\lambda_0 + \lambda_1) - c_u. \tag{6}$$

In this section, I assume that the quality improvement from the introduction of the product of quality q_2 is moderately large and thus, the following assumption holds:

Assumption 2 (A2) (a) $\Delta q^{'} + \alpha\lambda_2 + \alpha\lambda_0(1 - 2x_0) - \alpha\lambda_1 - c_u < 0,\ 0 \leq x_0 \leq 1$ or (b) $\Delta q^{'} + \alpha\lambda_2 - \alpha\lambda_0 + \alpha\lambda_1(1 - 2x_1) - c_u < 0,\ 0 \leq x_1 \leq 1$.

This assumption says that when compatibility is not supported, date t=1 customers will not buy the rival's product of quality q_2 after purchasing q_1 and thus, we restrict attention

[20] Note that the facts that the product of quality q_0 is not sold in the second period and thus, there is not a third choice of purchasing q_0 for the new second period customers as well as that old second period customers ($\lambda_0 + \lambda_1$) have purchased q_1 in the first period will become apparent in the first period analysis.

to moderately high values of quality improvements relative to network effects and the cost of learning how to use the new product. In our benchmark analysis, we will assume that A2a) holds.

Case 1: $\Delta q^{'} > \alpha(\lambda_0 + \lambda_1)$.

In this scenario, the prices at date t=2 are given by the expressions:

$$p_{22} = \Delta q^{'} - \alpha(\lambda_0 + \lambda_1), \; p_{12} = 0. \tag{7}$$

Date t=1 If all new customers (λ_1) buy the product of quality q_1, their total discounted utility given the dominant firm's price p_{11} is $q_1+\delta q_1+\alpha(\lambda_0+\lambda_1)+\delta\alpha(\lambda_1+\lambda_0)-c-p_{11}$.[21] Thus, the optimal dominant firm's price to λ_1 customers if they cannot postpone their purchase is:

$$p_{11} = q_1 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta\alpha(\lambda_0 + \lambda_1) - c.^{22} \tag{8}$$

If an old customer purchases q_1, given the dominant firm's upgrade price p_{10}, her total discounted utility is $q_1+\delta q_1+\alpha(\lambda_0+\lambda_1)+\delta\alpha\lambda_1+\delta\alpha\lambda_0 x_0^{''}-c_u-p_{10}$, as from assumption A2a), she knows that the measure λ_1 of new date 1 customers will not purchase the new product at date 2 after purchasing q_1 today and $x_0^{''}$ is the old date 1 customers' fraction that will also own the product of quality q_1 at date t=2. If she and all the other old date t=1 consumers initially keep q_0, her total discounted expected utility is $q_0 + \delta q_2 + \alpha\lambda_0 + \delta\alpha\lambda_2 + \delta\alpha\lambda_0 x_0 - \delta c_u - \delta p_{20}^{'e}$ where $p_{20}^{'e} = q_2 - q_1 - \alpha\lambda_0 - \alpha\lambda_1 + \alpha\lambda_2$ is the price she expects to pay in order to purchase q_2 tomorrow if all other old date t=1 customers either stick to q_0 or purchase q_1 at date t=2. An old first period consumer buys q_1 at date t=1 if her total discounted payoff marginally exceeds her total expected discounted payoff from sticking to q_0:

$$q_1 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta\alpha\lambda_1 - c_u - p_{10} > q_0 + \delta q_1 + \alpha\lambda_0 + \delta\alpha\lambda_0 + \delta\alpha\lambda_0 + \delta\alpha\lambda_1 - \delta c_u.$$

[21] Similarly to the economy operating under compatibility, the maximum price the dominant firm could charge these customers for q_0 is strictly smaller.

[22] See the Appendix for the price these customers are willing to pay if they can postpone their purchasing decision.

Thus, the first period price for these consumers is:

$$p_{10} = \Delta q + \alpha\lambda_1 - c_u(1-\delta) - 2\delta\alpha\lambda_0 - \varepsilon, \tag{9}$$

where ε is an infinitesimally small positive number. Note that this price is strictly smaller than the optimal price that the dominant firm would set when there is compatibility in the market.

Case 2: $\alpha(\lambda_0 + \lambda_1) - \alpha\lambda_2 \leq \Delta q' < \alpha(\lambda_0 + \lambda_1)$.

In this scenario, the product of quality q_2 does not allow the rival to generate any revenue in the second period. Instead, new date 2 customers purchase the product of quality q_1, as price competition leads to

$$p_{12} = q_1 - q_2 + \alpha(\lambda_0 + \lambda_1) - \varepsilon, \tag{10}$$

for a small positive number ε.

Date t=1 **Assumption 3 (A3)** $F < EV(R)$, where $EV(R)$ is the expected value of the rival's revenue.

This assumption says that the cost of development does not, per se, deter the rival firm from investing into the new product, as the probability distribution Φ regarding the rival's magnitude of innovative step and the market size are such that they guarantee that the rival's expected profit by investing is positive.

In this case, the dominant firm can charge higher prices to new date t=1 customers compared to the scenario of mandatory compatibility.[23] In order to focus on the effects of dominant firms' refusals to supply compatibility, we consider the case that the market leader's benefit from incompatibility through the higher price set to both new date t=1 and new date t=2 customers outweighs his lost revenue from the lower price set to old date t=1

[23] See the Appendix for the calculation of these prices.

customers.

Depending on the quality improvement and for different values of the network and the market size parameters, we identify the following scenarios:

S1 a) $\Delta q' < \min\{\alpha(\lambda_0+\lambda_1), c_u(\lambda_0+\lambda_1)\}$, b) $\Delta q' < \alpha(\lambda_0+\lambda_1)$, $\Delta q' \geq c_u(\lambda_0+\lambda_1)$. This scenario implies that the quality improvement from the introduction of q_2 is small relative to network externalities.

S2 a) $\Delta q' \geq \alpha(\lambda_0+\lambda_1)$, $\Delta q' > c_u(\lambda_0+\lambda_1)$, b) $\Delta q' \geq \alpha(\lambda_0+\lambda_1)$, $\Delta q' < c_u(\lambda_0+\lambda_1)$. This scenario occurs when the quality differential is relatively large compared to the extent of network effects.

In a laissez faire economy, the dominant firm compares its profit under the two regimes and decides whether to support compatibility or not. The next proposition summarizes the equilibrium outcome and holds independently of consumers' ability to postpone their purchasing decision:[24]

Proposition 2 *If S1 holds, the dominant firm refuses to support compatibility and all customers purchase the product of quality q_1 in both periods. If S2 holds, the dominant firm offers compatibility to the rival's products and either all or only the new date t=2 consumers purchase the product of quality q_2 at date t=2.*

The dominant firm's optimal choice is to refuse to offer compatibility for quality improvements from the introduction of the product of quality q_2 that are smaller relative to network effects. On the other hand, if the quality improvement from the rival's new product is large relative to network externalities, the dominant firm's optimal choice is to support compatibility because it can absorb at date t=1 more of the higher total expected discounted surplus, which is higher when compatibility is present. More precisely, old date t=1 consumers' net total discounted expected payoff if they initially keep the version of quality q_0 is

[24] See the Appendix for the dominant firm's compatibility and price choices when consumers can postpone their purchase and the rival cannot price discriminate.

greater if incompatible networks arise and thus, the dominant firm is better-off by supporting compatibility with the rival.

Social Optimum/ Consumers Welfare

It is important to analyze the social efficiency of the equilibrium results already obtained in the previous subsection as well as the effects of dominant firms' refusals to support compatibility on social efficiency and consumer surplus.

If the product of quality q_1 is used in both periods, social welfare is:

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

If the superior product of quality q_2 is used by all customers at date t=2, social welfare becomes:

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

where in the second period, all customers join a network of maximum size. Comparing the expressions above yields the socially optimal outcome:

Proposition 3 *It is socially efficient if (a) the product of quality q_1 is used for two periods if S1a) or S2b) holds, (b) the product of quality q_2 is used by the whole market if S1b) or S2a) holds.*

It is socially efficient if the good of quality q_1 is sold for both periods when the benefit from everyone purchasing it is smaller than the cost of learning how to use the new product ($\Delta q' < c_u(\lambda_0 + \lambda_1)$). When the last inequality is reversed, social optimality is achieved when the superior product is used by the whole market at date t=2.

The next proposition highlights the potential inefficiency that may arise in markets that operate under a laissez faire competition law and under mandatory compatibility:

Proposition 4 *(a) If S1a) holds, an economy that mandates compatibility leads to the inefficient introduction of the product of quality* q_2*.(b) There is no inefficiency in the laissez faire market if the network parameter is 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 competition law may lead to inefficient technological slowdown when S1b) holds.*

An economy mandating compatibility may lead to the inefficient introduction of the product of quality q_2, while society would be better-off without it when the social benefit from its introduction is smaller than the social cost of adopting it (S1a). More importantly, a laissez faire market leads to social efficiency when network effects are relatively weak ($\alpha < c_u$). These results are important, as they indicate that mandated compatibility by Competition Authorities may lead to socially inefficient outcomes and the social and private firms' incentives for technological improvement are aligned in a laissez faire market when network effects are weak. On the other hand, a laissez faire market may lead to inefficient technological slowdown for relatively strong network effects ($\Delta q^{'} < \alpha(\lambda_0 + \lambda_1)$) and for negligible values for the cost of learning how to use the new product relative to the quality improvement from its introduction ($\Delta q^{'} \geq c_u(\lambda_0 + \lambda_1)$). In particular, it may be socially efficient if all consumers use the new product and nevertheless, the refusal to support compatibility leads to the inefficient use of the dominant firm's product of quality q_1 for both periods.

The construct of social surplus may not be used by Competition Authorities, which may be interested in maximising consumer surplus. Thus, the next proposition looks at the effects of dominant firms' refusals to supply compatibility that may arise in a laissez faire market (S1) on consumer surplus:

Proposition 5 *Refusals to supply compatibility maximise consumer surplus.*

Consumer surplus is maximised when compatibility is not supported in a laissez faire economy compared to the economy that mandates compatibility. Refusals to support compatibility lead to more fierce competition between the rivals' incompatible networks that reduce equilibrium prices. Thus, when network effects are weak, both consumer surplus and social welfare are maximised under a laissez faire economy. These results are important contributing to the discussion among academics and policy makers regarding the desirability of a more interventionist competition law, as they imply that a laissez faire economy is preferable for consumers and society and mandated compatibility by Competition Authorities decreases consumer surplus and may be socially inefficient.

4 Applications/ Discussion/ Future Research

This article analyses dominant firms' behaviour towards the compatibility of their durable network goods and the welfare effects from their refusals to support compatibility. By using a sequential game, we give a smaller rival 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 moderately large quality improvement by the rival, strategic pricing leads the dominant firm to support compatibility even if it could exclude its rival from using its network.

Regarding welfare, an economy that mandates compatibility leads to a decrease in consumer surplus and possibly to the inefficient introduction of a relatively less innovative product. We also find that when network effects are weak, a laissez faire market converges to social efficiency and even when compatibility is not supported, consumers are better-off due to the higher degree of competition that reduces equilibrium prices when incompatible networks arise.

An important application captured by the model comes from the 2008 European Commission case against Microsoft regarding its office productivity suite highlighted earlier in the introduction. Although Microsoft's compliance to compatibility was enforced by the European Commission, this mandate may have been harmful for society. In particular, Microsoft Office 2007 was followed by Corel's WordPerfect Office suite in 2008 that introduced negligible quality improvements. Microsoft's denial to support compatibility would have a twofold effect: First, it would lead to an increase in consumer welfare due to a higher degree of competition between incompatible networks. Second, as proposition 4 shows, a market operating under a laissez faire competition policy towards intellectual property rights would lead to social efficiency, assuming that network effects are weak relative to the cost of learning the new product. Moreover, mandating compatibility would lead to inefficiency, as society would have been better-off without the new product (4a).

The policy implication of these findings is that Competition Authorities should investigate whether mandating compatibility may sometimes be socially unwelcome without necessarily benefiting consumers or even harming them. Instead, markets that allow unilateral refusals to supply interoperability information may possibly lead to efficient outcomes and improve consumers' welfare. In an economy where network effects are present, this exercise is not trivial but if network effects are not strong and quality improvements are moderate, an economy operating under a laissez faire competition law generates social efficiency and maximises consumer welfare.

Nevertheless, there are a number of issues that are important and are not addressed in this article. Firstly, current work looks at the role of information asymmetry in this setting of sequential innovation. Moreover, a model that will test empirically our results could validate our predictions. It would also be interesting to study the competitors' interoperability/investment decisions in the presence of stochastic demand.

5 Appendix

A. Moderate quality improvements/ Date t=1 Prices to New first period customers (λ_1) if they can postpone their purchase/ The rival can price discriminate

Compatibility

We analyse the case where date t=1 customers purchase the product of quality q_2 at date t=2. Given the first period price, p_{11}, new date t=1 customers' total discounted utility if they buy q_1 is $q_1 + \delta q_2 + \alpha(\lambda_0 + \lambda_1) + \delta\alpha - c - \delta c_u - p_{11} - \delta p_{21}$, where $p_{21} = \Delta q' + \alpha\lambda_2 - c_u$. If they all postpone their purchase, they would belong to a network of size $\lambda_1 + \lambda_2$ and the rival's second period price can be computed by the equality:

$$q_2 + \alpha - c - p'_{22} = q_1 + \alpha(\lambda_1 + \lambda_2) - c - p'_{12},$$

or equivalently $p'_{22} = \Delta q' + \alpha\lambda_0$. Thus, their outside opportunity if they wait in the first period is $\delta(q_2 + a - c - p'_{22}) = \delta[q_1 + \alpha(\lambda_1 + \lambda_2) - c]$ and the dominant firm's price is: $p_{11} = q_1 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta\alpha\lambda_0 - \delta\alpha\lambda_2 - c(1 - \delta)$.

Incompatibility

We focus on the case that $\Delta q' \geq \alpha(\lambda_0 + \lambda_1)$.

New first period customers' total discounted utility if they purchase q_1 is $q_1 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta\alpha(\lambda_0 + \lambda_1) - c - p_{11}$. If they postpone their purchase, they will subsequently belong to a network of size $\lambda_1 + \lambda_2$ and their total discounted utility is $\delta(q_2 + \alpha(\lambda_1 + \lambda_2) - c - p'_{22})$, where $p_{22}^{'}$ is the second period price that can be computed in the following equation:

$$q_2 + \alpha(\lambda_2 + \lambda_1) - c - p_{22}^{'} = q_1 + \alpha - c - p_{12}^{'},$$

or equivalently $p_{22}^{'} = \Delta q^{'} - \alpha\lambda_0$. Their net expected utility if they wait to make their purchasing decision tomorrow is $\delta(q_1 + a - c)$. Thus, the maximum price these customers are willing to pay today to buy q_1 is $p_{11} = q_1 + \alpha(\lambda_0 + \lambda_1) - \delta\alpha\lambda_2 - c(1-\delta)$.

B. Moderate Quality Improvements/ Incompatibility/ Prices when $\Delta q^{'} < \alpha(\lambda_0 + \lambda_1)$.

If new customers (λ_1) buy the good of quality q_1, their total discounted utility is $q_1 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta\alpha - c - p_{11}$ and the maximum price the dominant firm can charge them is

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

If an old customer buys the product of quality q_1, her total discounted utility is $q_1 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta\alpha\lambda_1 - c_u - p_{10}$, as from assumption A1a), new date t=1 customers always stick to q_1 after purchasing it. If she and all the other members of her group stick to q_0, she expects to purchase q_2 tomorrow, even if all the other old date t=1 customers all either purchase q_1 tomorrow or all stick to q_0 by paying a price: $p_{21}^{e} = \Delta q^{'} + \alpha\lambda_2 - \alpha(\lambda_0 + \lambda_1)$ due to the fact that new date t=2 consumers would also buy q_2 tomorrow. Thus, her total expected discounted payoff by sticking to q_0 is $q_0 + \delta q_2 + \alpha\lambda_0 + \delta\alpha(\lambda_2 + \lambda_0) - \delta c_u - \delta[\Delta q^{'} + \alpha\lambda_2 - \alpha(\lambda_0 + \lambda_1)] = q_0 + \delta q_1 + \alpha\lambda_0 + 2\delta\alpha\lambda_0 + \delta\alpha\lambda_1 - \delta c_u$ and initially purchases the product of quality q_1 even if all other consumers from her group stick to q_0 when her discounted payoff from upgrading to q_1 marginally exceeds her total expected discounted payoff from sticking to q_0:

$$q_1 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta\alpha\lambda_1 - c_u - p_{10} > q_0 + \delta q_1 + \alpha\lambda_0 + 2\delta\alpha\lambda_0 + \delta\alpha\lambda_1 - \delta c_u,$$

or equivalently $p_{10} = \Delta q + \alpha\lambda_1 - 2\delta\alpha\lambda_0 - c_u(1-\delta) - \varepsilon$.

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Figures and Tables

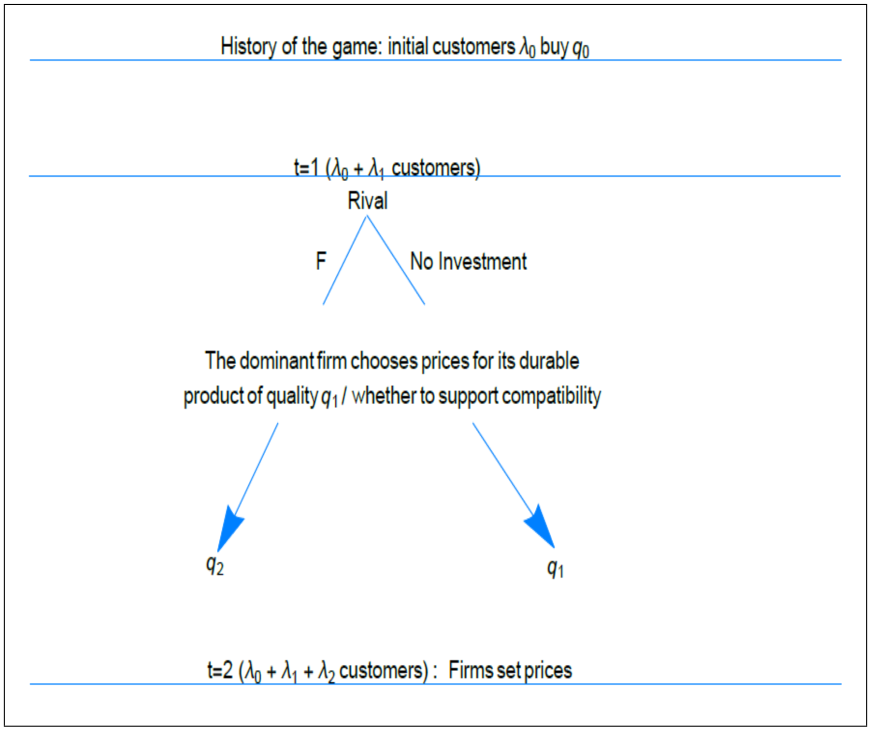

Figure 1: Timing of the economic agents' moves.