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

Job Market Paper

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Abstract

This paper contributes to the understanding of firms’ decisions regarding compatibility of durable network goods in the presence of forward-looking consumers. We consider sequential, imperfectly substitutable product innovations, where a smaller rival can build on the dominant firm’s existing knowledge. For moderately large quality improvements expected to be introduced by the rival, the market leader supports compatibility independently both of the rival’s ability to price discriminate and consumers’ (un)willingness to postpone purchasing decisions. This is because strategic pricing allows the dominant firm to extract more of the higher total expected surplus that emerges when interoperability is present. Furthermore, compatibility does not de-facto maximise social welfare, and there is no market failure when network effects are weak. For higher expected quality improvements, when the rival lacks the ability to price discriminate, consumer surplus is maximised under a laissez faire Competition Law even though the dominant firm does not offer compatibility independently of consumers’ ability to delay their purchasing decision.

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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 duty 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 should provide interoperability\textsuperscript{3} information to rivals. Failure to do so is a potential violation of Article 102 (ex article 82) of the European Competition Law and often leads to regulation forcing the dominant firms to allow compatibility.\textsuperscript{4} In a nutshell, the 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.\textsuperscript{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 software that was interoperable with Microsoft Office 2007.\textsuperscript{6} The case followed a complaint\textsuperscript{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.\textsuperscript{8}

In contrast, in the United States, a more laissez faire Competition Law with respect to the Intellectual Property Rights owners 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

\textsuperscript{3}We will use the terms interoperability and compatibility interchangeably throughout the paper.

\textsuperscript{4}See http://ec.europa.eu/competition/antitrust/legislation/handbook_vol_1_en.pdf

\textsuperscript{5}See http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52009XC0224(01)&from=EN


\textsuperscript{7}See http://www.techhive.com/article/124813/article.html

property to rivals, or to refuse to do so".\textsuperscript{9} 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".\textsuperscript{10}

Investigating dominant firms’ attitude towards interoperability and how these decisions affect their competitors’ incentives to invest into improving product quality is very important. This paper provides such an investigation. More precisely, it provides answers to the following questions: Will the dominant firm initially invest in improving its product? If it invests, will it subsequently block interoperability with a rival future innovator? If there is incompatibility, does this de-facto mean that it is socially undesirable? Could a market where compatibility is voluntary converge to interoperability when it is socially efficient? Are consumers better-off in an economy that mandates compatibility?

To answer these questions, a sequential game is built in which the market leader initially chooses whether to invest in substantially improving its product for computer software applications which are durable network goods. If the leader invests, in the subsequent period, a smaller, innovative rival may further invest in a substitute innovative product. The rival’s choice crucially depends on the importance of her idea and the dominant firm’s future anticipated 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 that emerge as follow-on, non-drastic substitutable innovations after the dominant firm’s invention hits the market in a Schumpeterian scenario of creative destruction. Our analysis shows that there are market conditions under which the dominant firm initially invests. We find that given modest structure on consumers’ preferences and the rival’s behaviour, the market leader chooses to supply interoperability information when he anticipates a moderately large quality improvement from the rival. This reflects that strategic pricing allows him to extract more of the higher future surplus in the present market when the competitor has the power to

\textsuperscript{10}See http://www.justice.gov/atr/public/reports/236681_chapter7.htm
price discriminate independently of new first period customers’ (un)willingness to postpone purchase decisions. An analogous result arises even when the rival cannot price discriminate as long as potential first period consumers can delay their purchase decision. Regarding welfare, we find that mandated compatibility may lead to the inefficient introduction of less innovative products. When network effects are strong, a laissez faire market could lead to inefficient technological slowdown, but for relatively weak network externalities, a laissez faire economy leads to social efficiency. For a more innovative rival’s product, the dominant firm always refuses to offer compatibility. In turn, when the rival lacks the ability to price discriminate, although the economy that mandates compatibility or operates under a laissez faire Competition Law may lead to inefficiency, the presence of incompatibility benefits new second period consumers as their surplus is higher when compatibility is not supported due to the competitive pressures that reduce the equilibrium prices. Our conclusions cast doubts on whether mandatory interoperability, while trying to support competition, allow technological advancement and protect consumers from abusive behaviour, may actually distort the market and lead to both socially undesirable results and customers’ harm.

This paper is organized as follows: in the following subsection, related literature is discussed. Section 2 presents the model. In Section 3 we consider the case where the anticipated second period quality improvements are moderately large. We look at equilibrium outcomes when compatibility is mandatory and when the economy operates under a laissez faire Competition Law toward Intellectual Property Rights holders. We then analyze the problem faced by a social planner who wishes to maximise social surplus and we compare equilibrium outcomes with the social optimum. Section 4 looks at the case where the superior second period product is expected to be more innovative. We analyze first the market equilibrium outcome and determine the economy that maximises consumers’ welfare because the first welfare measure fails to answer which economy is socially preferable. Section 5 provides applications of the model and concludes.
1.1 Related Literature

This work contributes to the literature regarding firms’ incentives towards compatibility with their competitors when network effects are present. In a seminal paper, 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) 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: 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. In contrast, both firms find inter-network compatibility profitable. Focusing on direct network effects and durable goods, and contrary to the literature, we consider improvements in product quality and find that the dominant firm may support compatibility with its rival when the quality improvement expected to be introduced by the smaller firm is moderately large. However, the dominant firm does not offer compatibility to a rival that is expected to sell a sufficiently innovative product.

Economides (2006) argues that it is socially efficient to move towards compatibility. 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 because unlike a market that operates under a laissez faire Competition Law towards Intellectual Property Rights holders, a regime of compulsory compatibility may result in the inefficient introduction of a higher quality product, when the expected quality improvement is small relative to network externalities, in which case society would be better-off without it. For sufficiently innovative expected product improvements, consumers gain when compatibility is not supported due to the lower prices that emerge compared to the regime of mandatory compatibility.

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 the private firms’ incentives for producing better product versions are aligned when network effects are not too strong.

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 compared to the case that innovation is concentrated in one firm. We are mainly interested in the interplay between Intellectual Property Rights protection and firms’ behaviour towards compatibility. In contrast to these papers, we find that the first innovator will voluntarily offer compatibility to rivals because strategic pricing enables him to absorb more of the second period expected profit when he anticipates a moderately large
improvement from the second innovator. We depart from all the papers above by considering a market with durable, network goods.

2 The Model

Our objective is to give some insights about 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 we have in mind is the market for computer software applications as highlighted in the introduction.

2.1 Supply

The model is cast in discrete time in a three period horizon. When compatibility is not mandatory, the sequence of events in the supply side is as follows (see figure 1): at $t=0$, the dominant firm has an installed base $\lambda_0$ of consumers. Consistent with the Microsoft Office case analyzed in the introduction, the market leader decides whether to invest a fixed amount $F$ to achieve a substantial improvement of his product, raising its quality from the level $q_0$ to a higher level $q_1$.\(^\text{11}\) 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 opening and saving documents that are created with the upgrade.\(^\text{12}\)

At the beginning of period $t=1$, if the dominant firm decided to postpone its investment decision, it is still the only potential inventor of the product of quality $q_1$ at $t=2$. If the dominant firm initially innovates, the rival can choose to incur a fixed cost $F$ to create a substitute product of higher expected quality $q_2^e > q_1$ but only undertakes R&D when the

\(^{11}\)We follow Ellison and Fudenberg (2000) who also assume quality as a positive, real number.

\(^{12}\)See Ellison and Fudenberg (2000) for a paper that backward compatibility and forward incompatibility are also present.
project has positive net present value. 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?\textsuperscript{13} After all, he knows his products and he also knows that his 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 the smaller competitor may have a better, future idea. All innovations occur with certainty and the magnitude of the quality improvements is treated as exogenous.\textsuperscript{14}

At the end of period 1, the market leader sets the price(s) for his product(s) and decides whether to support compatibility by eliciting interoperability information about his ver-

\textsuperscript{13}In a related paper, we allow both firms to be future potential innovators.

\textsuperscript{14}In a related paper, we consider the case where innovation does not occur with certainty and current work endogenizes the quality improvements.
sion(s). This compatibility choice is a binary decision and following Malueg and Schwartz (2006), we assume that it 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 comes free of charge.\footnote{See Malueg and Schwartz (2006).}

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.

If compatibility is expected not to be supported, the rival firm may still innovate. More precisely, if the market leader is expected to refuse to offer compatibility, the rival has an alternative route to innovate that does not use the dominant firms’ 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.

At date $t=2$, both risk neutral, profit maximising firms set their prices à la Bertrand. Moreover, products are functional for two periods. Consistent with software applications, we assume that the marginal cost of production is zero for all versions. Note that although we assume that the initial market leader has the power to price discriminate in period 1, we analyze both cases where in period 2, the rival has the ability or cannot price discriminate between the old and the new consumers.

### 2.2 Demand

Consumers are identical and have a per period unitary demand. At date $t=0$, there is a mass $\lambda_0$ of customers in the economy who have previously purchased the product of quality $q_0$, and future generations arrive in constant flows $\lambda_1, \lambda_2$ at dates $t=1,2$, respectively.

At the end of period 1, new customers ($\lambda_1$) observe the dominant firm’s price of the
product of quality $q_1$ and $q_0$. Their utility is partially dependent on direct network effects captured by a parameter $\alpha$. Thus, if they purchase the product of quality $q_1$, their utility (gross of the price that will be determined in the next section) is $q_1 + \alpha(\lambda_0 + \lambda_1) - c$ independently of what other customers do, where $\lambda_0 + \lambda_1$ is the market size at $t=1$ and $c$ is these customers’ cost of learning how to use the product.\[^{16}\] If they buy the product of quality $q_0$, their utility is $q_0 + \alpha \lambda_0 x_0 + \alpha \lambda_1 x_1 - c$, where $x_0$, $x_1$ are the $\lambda_0$ and $\lambda_1$ customers’ fractions that stick and buy $q_0$, respectively. We will analyze both cases that $\lambda_1$ customers cannot postpone their purchase at $t=1$ and when they are willing to wait. Old customers ($\lambda_0$) own the product of quality $q_0$ and observe the market leader’s upgrade price for his product $q_1$. If they buy it, their benefit is $q_1 + \alpha(\lambda_0 + \lambda_1) - c_u$, where $c_u$ is the additional adoption cost they need to incur ($c_u < c$). If they stick to the initial version, their utility is $q_0 + \alpha \lambda_0 x_0 + \alpha \lambda_1 x_1$. All date $t=1$ customers’ overall benefit depends on their forecasts for the prices at $t=2$ and the way that customers make purchase decisions. These forecasts reflect consumers’ information when they are called to make their decision and are aligned, in equilibrium.

At date $t=2$ and if the rival sells her product of quality $q_2$, $\lambda_0 + \lambda_1$ customers observe the prices. If these customers stick to $q_1$, their utility is $q_1 + \alpha \lambda_2 x_2 + \alpha(\lambda_0 + \lambda_1) x_1$, where $x_1, x_2$ are the date $t=2$ old and new customers’ fractions that also own it at $t=2$.\[^{17}\] When compatibility is present, their utility from buying $q_2$ is $q_2 + \alpha - c_u$ due to backward compatibility of the product of quality $q_2$, where the date $t=2$ market size is normalized to unity and $c_u$ is their adoption cost. If compatibility is not supported, these customers’ utility if they purchase $q_2$ is $q_2 + \alpha \lambda_2 (1 - x_2) + \alpha(\lambda_0 + \lambda_1)(1 - x_1) - c_u$, where $1 - x_1 \geq 0, 1 - x_2 \geq 0$ are the date $t=2$ old and new customers’ fractions that also purchase it. Old customers’ $(\lambda_0 + \lambda_1)$ purchasing decision resembles a coordination game and although it has multiple equilibria,

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

\[^{17}\]In the next section we will calculate the first period price that these customers pay to buy the product of quality $q_1$. 
we assume that they coordinate on the Pareto optimal outcome. Thus, when compatibility is present, they buy the new product even if all other customers of their class stick to \( q_1 \) if

\[
\Delta q + \alpha \lambda_2 (1 - x_2) - c_u > 0,
\]

where \( \Delta q = q_2 - q_1 \) is the quality improvement from the introduction of the new product \( q_2 \). If there is incompatibility, they choose to buy \( q_2 \) if

\[
\Delta q^c + \alpha \lambda_2 (1 - 2x_2) - \alpha (\lambda_0 + \lambda_1) - c_u > 0.
\]

At date \( t=2 \), new consumers (\( \lambda_2 \)) observe the prices and decide which product to buy. If they purchase the dominant firm’s product of quality \( q_1 \), their utility is

\[
q_1 + \alpha \lambda_2 x_2 + \alpha (\lambda_0 + \lambda_1)x_1 - c.
\]

If they buy the product of quality \( q_2 \) and compatibility is present, their utility is

\[
q_2 + \alpha - c
\]

while when compatibility is not supported, their benefit from getting the product of quality \( q_2 \) is

\[
q_2 + \alpha \lambda_2 (1-x_2) + \alpha (\lambda_0 + \lambda_1)(1-x_1) - c.
\]

These customers’ purchasing decision also resembles a coordination game and following the literature, we assume they behave as a single player. Thus, when compatibility is supported, they buy \( q_2 \) if

\[
\Delta q + \alpha (\lambda_0 + \lambda_1)(1-x_1) > 0,
\]

where \( \Delta q = q_2 - q_1 \) is the quality improvement from introducing \( q_2 \). This expression is always positive and implies that new customers (gross of prices) are always better-off if they buy the product of quality \( q_2 \). In contrast, when there is incompatibility in the market, these customers buy the product of quality \( q_2 \) if

\[
\Delta q + \alpha (\lambda_0 + \lambda_1)(1-2x_1) > 0.
\]

This last expression may take a negative sign if old customers stick to the product \( q_1 \) in the second period. All consumers make their purchasing decisions simultaneously and prefer a new product rather than an older version when they gain the same net expected utility by either of these two choices.

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19 See Ellison and Fudenberg (2000).
3 Moderate expected quality improvements

3.1 Market outcome

We start by solving for equilibrium outcomes when compatibility is mandatory followed by an economy that operates under a laissez faire Competition Law. Although we solve for equilibria after the product of quality \( q_1 \) hits the market, we will not neglect to check the dominant firm’s initial investment decision at date \( t=0 \). Our benchmark case will consider the scenario that new first period customers cannot postpone their purchase and the rival firm has the power to price discriminate.

3.1.1 Mandatory compatibility

\textbf{Date } \( t=2 \) New customers in the second period (\( \lambda_2 \)) can choose to buy either the rival firm’s product of quality \( q_2 \) or the market leader's previous version \( q_1 \).\(^{20}\) Given the price charged by the rival, their utility if they buy the version of quality \( q_2 \) is \( q_2 + \alpha - c - p_{22} \), where the first and second subscripts in the price \( (p_{22}) \) are related to the quality level of the product purchased and the type of customers buying the good, respectively. If they choose to buy \( q_1 \), their utility given the price set by the dominant firm \( (p_{12}) \) 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 second period customers’ fractions that use \( q_1 \).\(^{21}\) New customers coordinate, given prices, to what is best for all of them and thus, they will choose to buy \( q_2 \) if:

\[
p_{22} - p_{12} \leq \Delta q + \alpha (\lambda_0 + \lambda_1) (1 - x_1),
\]

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 old second period customers \( (\lambda_0 + \lambda_1) \). If they pur-

\(^{20}\)Note that it will become apparent in the first period analysis 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.

\(^{21}\)It will become apparent in the first period analysis that the old second period customers \( (\lambda_0 + \lambda_1) \) purchased \( q_1 \) in the previous period.
chase the product of quality $q_2$, their utility given the rival’s price $p_{21}$ is $q_2 + \alpha - c_u - p_{21}$ independently of other customers’ choices. If they stick to $q_1$, their utility will be $q_1 + \alpha \lambda_2 x_2 + \alpha (\lambda_0 + \lambda_1) x_1$, where $x_1, x_2$ are the $\lambda_0, \lambda_1, \lambda_2$ customers’ fractions that either stick or buy $q_1$ in the second period, respectively. If old consumers make their purchasing decisions independently of what other old customers do, they will purchase $q_2$ even if all other $\lambda_0 + \lambda_1$ stick to $q_1$ when:

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

The next assumption holds:

**Assumption 1 (A1)** $\Delta q \geq \frac{c_u - \alpha \lambda_2}{\lambda_0 + \lambda_1}$.

This assumption says that the rival firm is better-off by serving the whole market when she lacks the ability to price discriminate and it allows the linkage between the two periods. It also implies that at date $t=2$, old consumers (gross of prices) benefit from purchasing the product of quality $q_2$, allowing us to focus on the interplay between the extent of network externalities and the second period quality improvement.

Thus, Bertrand competition leads the second period equilibrium prices to $p_{22} = \Delta q + \alpha (\lambda_0 + \lambda_1)$, $p_{21} = \Delta q + \alpha \lambda_2 - c_u$, $p_{12} = 0$.

**Date t=1** The next assumption holds regarding the development cost:

**Assumption 2 (A2)** $F < \lambda_2 [\Delta q^e - \alpha (\lambda_0 + \lambda_1)]$, where $\Delta q^e = q_2^e - q_1$ is the expected quality improvement from the introduction of the product of quality $q_2^e$ in the second period.

This assumption says that the cost of development does not, per se, deter the rival firm from investing into the new product of expected quality $q_2^e$ as the market size is large enough to enjoy positive profits in the second period.

Let’s first think of the maximum price the dominant firm can charge to the new first period customers ($\lambda_1$) by selling the product of quality $q_1$. If these customers buy the superior version $q_1$ and they conjecture that they will coordinate on the Pareto optimum tomorrow, their total net discounted expected utility given the price set by the dominant
firm \((p_{11})\) if they expect they will purchase \(q'_2\) in the second period is \(q_1 + \delta q'_2 + \alpha(\lambda_0 + \lambda_1) + \delta \alpha - c - \delta c_u - p_{11} - \delta p'_{21}\) independently of what other customers do where \(p'_{21}\) is the price they expect to pay in order to buy \(q'_2\) in the second period and \(\delta\) is the common discount factor in the economy. Thus, the maximum total expected price they are willing to pay is \(p_{11} + \delta p'_{21} = q_1 + \delta q'_2 + \alpha(\lambda_0 + \lambda_1) + \delta \alpha - c - \delta c_u\) if they cannot postpone their purchase.\(^{22}\)

Note that for a sufficiently innovative product of quality \(q_1\), the dominant firm’s maximum price to these consumers by selling the product of quality \(q_0\) is strictly smaller.

Let’s now turn our attention to the old consumers \((\lambda_0)\). By upgrading to \(q_1\) and if they forecast that they will also coordinate to the Pareto optimum tomorrow, their total expected discounted utility given the price \(p_{10}\) for upgrading is \(q_1 + \delta q'_2 + \alpha(\lambda_0 + \lambda_1) + \delta \alpha - c - \delta c_u - p_{10} - \delta p'_{20}\) independently of what others do, where \(p'_{20}\) is the price they expect to pay in the second period to buy the superior product \(q'_2\) over the alternative of sticking to \(q_1\). If they initially choose to stick to \(q_0\), they may expect to keep it or either upgrade to \(q_1\) or purchase \(q'_2\) in the second period. Their total discounted expected utility if they expect to purchase \(q'_2\) in the second period is \(q'_0 + \delta q'_2 + a\lambda_0 x''_0 + \alpha \lambda_1 x''_1 + \delta \alpha - \delta c_u - \delta p'_{20}\), where \(p'_{20} = \Delta q'' + a\lambda_1(1 - x_1) + a\lambda_2(1 - x_2)\) is the price they expect to pay in order to get \(q'_2\) in the second period if they conjecture that they will coordinate on the Pareto optimum tomorrow and \(x''_0, x''_1\) are the \(\lambda_0, \lambda_1\) customers’ fractions who stick or buy \(q_0\) in the first period, respectively.\(^{23}\) So, they prefer to buy \(q_1\) when they make their purchasing decisions independently of what other old customers do if:

\[
p_{10} + \delta p'_{20} \leq \Delta q + \delta \Delta q'' + \alpha \lambda_1(1 - x''_1) + \delta \alpha \lambda_2(1 - x_2) + \delta \alpha \lambda_1(1 - x_1) - c_u
\]

where from the first period perspective, \(\Delta q = q_1 - q_0, \Delta q'' = q'_2 - q_1\) are the first and second period quality improvements, respectively. The price \(p_{10}\) is a decreasing function of the number of the new customers who buy the product of quality \(q_0\) in the first period \((x''_1)\).

\(^{22}\)See the Appendix for the case these customers are willing to postpone their purchase.

\(^{23}\)Check the Appendix for the price these customers expect to pay to buy \(q'_2\).
Thus, the optimal dominant firm’s choice is to stop selling the product of quality $q_0$ in the first period and the pricing decisions satisfy the expressions:

$$p_{i1} + \delta p_{e2i} = q_1 + \delta q_2 + \alpha(\lambda_0 + \lambda_1) + \delta \alpha - c - \delta c_u,$$  \hspace{1cm} (3)

$$p_{i0} + \delta p_{e20} = \Delta q + \delta \Delta q^e + \alpha \lambda_1 + \delta \alpha \lambda_2 + \delta \alpha \lambda_1 - c_u.$$  \hspace{1cm} (4)

We observe that the total maximum expected payment that new and old customers are willing to pay is fixed. The dominant firm’s optimal choice is to set:

$$p_{i1} = q_1 + \delta q_2 + \alpha(\lambda_0 + \lambda_1) + \delta \alpha - c - \delta c_u - \delta p_{e21},$$ \hspace{1cm} (3')

$$p_{i0} = \Delta q + \delta \Delta q^e + \alpha \lambda_1 + \delta \alpha \lambda_2 + \delta \alpha \lambda_1 - c_u - \delta p_{e20},$$ \hspace{1cm} (4')

where $p_{e21} = p_{e20} = \Delta q^e + \alpha \lambda_2 - c_u$.

\textbf{Date t=0}  In our analysis, we have considered that the market leader initially invests into substantially improving his product quality from quality level $q_0$ to a higher level $q_1$. If he postpones this decision to the first period (t=1), we assume that he is still the only firm that can improve his product. Thus, one may expect that the dominant firm would not initially invest as he would potentially remain the sole second period supplier in the scenario he forecasts that a smaller rival may innovate further in the future. However, this is only partially true if the initial market leader’s product of quality $q_1$ is sufficiently innovative. More precisely, it may be that his first period gain from selling the product of quality $q_1$ outweighs his second period monopoly loss.$^{24}$

The next proposition summarizes the market equilibrium outcome in an economy where compatibility is mandatory and it holds independently of the rival’s ability to price discriminate and new first period customers’ willingness to wait:

$^{24}$See the Appendix for the comparison of the dominant firm’s expected profits if he decides to postpone his investment decision or not.
Proposition 1 Under assumptions A1, A2, the dominant firm decides to stop selling the old version of quality $q_0$ in the first period. Instead, he sells the product $q_1$ to the new and the old first period customers. In the second period, the product of quality $q_2$ is sold by the rival to the whole market.

3.1.2 Laissez faire Competition Law

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

**Date $t=2$** If there is a product of quality $q_2$ in the market and all new second period customers ($\lambda_2$) buy it, their utility given the price charged by the rival firm ($p_{22}$) 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 given the dominant firm’s price $p_{12}$ is $q_1 + \alpha \lambda_2 + \alpha(\lambda_1 + \lambda_0)x_1 - p_{12}$, where $x_1$ is the old customers’ fraction that sticks to $q_1$ in the second period.\(^{25}\) Thus, $\lambda_2$ customers buy $q_2$ if:

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

Let’s turn our attention to the old second period customers ($\lambda_0 + \lambda_1$). Their utility if they purchase $q_2$ is $q_2 + \alpha(\lambda_0 + \lambda_1)(1 - x_1) + \alpha \lambda_2(1 - x_2) - c_u - p_{21}$ given the rival’s price $p_{21}$ while if they stick to $q_1$, their 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 customers’ fractions that stick or buy $q_1$ in the second period. If old customers make their purchase decision independently of what other old customers do, they will choose to buy $q_2$ even if all other old customers stick or buy $q_1$ ($x_1 = 1$) when:

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

\(^{25}\)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.
We make the following assumption with respect to the quality improvement from the introduction of the product of quality $q_2$:

**Assumption 3 (A3)** (a) $\Delta q + \alpha \lambda_2 (1 - 2x_2) - \alpha (\lambda_0 + \lambda_1) - c_u < 0$, $0 \leq x_2 \leq 1$, (b) $q_2 - q_1 \leq q_1 - q_0$.

The first part of the assumption (a) says that when compatibility is not supported, first period customers expect not to buy the rival’s product of anticipated quality $q_2^c$ and thus, we restrict attention to moderately high values of quality improvements relative to network effects. The second part of the assumption (b) says that a given investment leads to a smaller quality improvement in the second rather than in the first period when the product of quality $q_1$ is an important innovation. In the next section, we will relax assumption 3 when we consider a sufficiently innovative future product compared to the extent of network effects.

**Case 1:** $\Delta q < \alpha (\lambda_0 + \lambda_1)$.

In this scenario, the rival is deterred to invest and the dominant firm remains the sole supplier in the market at date $t=2$. Thus, his optimal choice is to set the monopoly price to $\lambda_2$ customers:

$$p_{12} = q_1 + \alpha - c. \tag{7}$$

**Date $t=1$** If new customers ($\lambda_1$) buy the good of quality $q_1$, their total expected discounted utility given the price charged by the dominant firm $p_{11}$ and their forecast of coordinating on the Pareto optimum tomorrow is $q_1 + \delta q_1 + \alpha (\lambda_0 + \lambda_1) + \delta \alpha - c - p_{11}$. \textsuperscript{26}

Let’s now turn our attention to the old consumers in the first period ($\lambda_0$). If they buy the product of quality $q_1$, their total expected discounted utility given the upgrade price charged by the dominant firm ($p_{10}$) is $q_1 + \delta q_1 + \alpha (\lambda_0 + \lambda_1) + \delta \alpha - c_u - p_{10}$, independently of what other customers do. If they stick to $q_0$, their expected utility by upgrading in the second period to $q_1$ is $q_0 + \delta q_1 + \alpha \lambda_0 x_0 + \alpha \lambda_1 x_1 + \delta \alpha - \delta c_u - \delta p_{10}^x$, where $p_{10}^x = \Delta q + \alpha \lambda_1 (1 - x'_1) + \alpha \lambda_2 (1 - x'_2) - c_u$.

\textsuperscript{26}Similarly with the case when compatibility is present, the dominant firm’s optimal price to these customers by selling $q_0$ is strictly smaller for a sufficiently innovative product of quality $q_1$. 

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is the price they expect to pay tomorrow in order to upgrade if they forecast they will coordinate on the Pareto optimum tomorrow.\textsuperscript{27} If old customers make their purchasing decisions independently of what other old customers do, they upgrade to $q_1$ in the first period even if all other old $\lambda_0$ consumers stick to $q_0$ if:

\[ p_{10} \leq \Delta q + \alpha \lambda_1 (1 - x_1) - c_u + \delta c_u + \delta p_{10}^e. \]

Notice that since the dominant firm’s profits are a decreasing function of the number of $\lambda_1$ customers that buy $q_0$ in the first period ($x_1$), its optimal choice is to stop selling the initial version in the first period (and $x_1 = 0$ in the inequality above). Thus, the first period prices are given by the expressions:

\begin{align*}
    p_{11} &= q_1 + \delta q_1 + \alpha (\lambda_0 + \lambda_1) + \delta \alpha - c, \quad (8) \\
    p_{10} &= \Delta q + \alpha \lambda_1 - c_u + \delta c_u + \delta p_{10}^e, \quad (9)
\end{align*}

where

\[ p_{10}^e = \Delta q + \alpha \lambda_1 + \alpha \lambda_2 - c_u. \quad (10) \]

**Case 2:** $\Delta q > \alpha (\lambda_0 + \lambda_1)$.

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

\begin{align*}
    p_{22} &= \Delta q - \alpha (\lambda_0 + \lambda_1), \quad p_{12} = 0. \quad (11)
\end{align*}

**Date $t=1$**  Let’s first think of the new customers in the first period ($\lambda_1$). If they buy the product of quality $q_1$, their total expected discounted utility given the dominant firm’s price $p_{11}$ is $q_1 + \delta q_1 + \alpha (\lambda_0 + \lambda_1) + \delta \alpha \lambda_1 + \delta \alpha \lambda_0 - c - p_{11}$ if they conjecture that they will coordinate

\textsuperscript{27}See the Appendix for the determination of this price.
on the Pareto optimum tomorrow.\textsuperscript{28}

Let’s now turn our attention to the old customers in the first period ($\lambda_0$). If they upgrade to $q_1$, given the dominant firm’s upgrade price $p_{10}$, their total expected discounted utility is 

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

if they forecast that they will coordinate on the Pareto optimum tomorrow. If they keep $q_0$, their total discounted expected utility if they expect to purchase $q_e$ is 

$q_0 + q_0 + (\lambda_0 x_2) + \alpha \lambda_1 x_2 + \delta \alpha \lambda_0 x_0 - \delta c_u - \delta p_{20}$

where $p_{20} = \Delta q - \alpha \lambda_0 + \alpha \lambda_1 (2x_1 - 1) + \alpha \lambda_2 (2x_2 - 1)$ is the price they expect to pay in order to purchase $q_e$ tomorrow if they conjecture they will also coordinate to the Pareto optimum in the following period and $x_0, x_1, x_2$ are the old and the new first period customers’ fractions that stick or buy $q_0$ today, respectively while $x_0, x_1, x_2$ are the old and new second period customers that are expected to purchase $q_2$ tomorrow.\textsuperscript{29} Old first period consumers buy $q_1$ in the first period even if all other customers of the same class choose $q_0$ ($x'' = 1$) if:

$p_{10} \leq \Delta q + \alpha \lambda_1 (1 - x'') - c_u (1 - \delta) - \delta \alpha \lambda_0 + \delta \alpha \lambda_1 x - \delta \alpha \lambda_2 (1 - x_2).$

Since $p_{10}$ is a decreasing function of the number of $\lambda_1$ customers who buy $q_0$ in the first period ($x''$), the dominant firm’s optimal choice is to stop selling $q_0$ in the first period (thus, $x'' = 0$ in the inequality above) and the first period price is:

$p_{10} = \Delta q + \alpha \lambda_1 - c_u + \delta c_u - \delta \alpha \lambda_0.$ \hspace{1cm} (12)

Note that this price is strictly smaller than the optimal price that the dominant firm would set when there is compatibility in the market. The optimal dominant firm’s price to $\lambda_1$ customers if they cannot postpone their purchase is:

$p_{11} = q_1 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta \alpha (\lambda_0 + \lambda_1) - c.$ \hspace{1cm} (13)

\textsuperscript{28}For a sufficiently innovative product of quality $q_1$, the maximum price the dominant firm could charge these customers for $q_0$ is strictly smaller.

\textsuperscript{29}See the Appendix for the calculation of this expected price.

\textsuperscript{30}See the Appendix for the price these customers are willing to pay if they can postpone their purchasing
The dominant firm’s initial choice to invest depends on the profitability of such a decision and commonly with the economy that mandates compatibility, there are market conditions that allow him to initially invest when his product of quality $q_1$ is sufficiently innovative even when he forecasts that the smaller rival will further improve product quality.\footnote{See the Appendix for the dominant firm’s calculated expected profits if he decides to postpone his investment decision or not.}

Depending on the quality improvement expected to be introduced by the competitor ($\Delta q^e$) and for different values of the investment ($F$), we identify the following scenarios:

**S1** \[ \Delta q^e - (\lambda_0 + \lambda_1)c_u < F < (\lambda_0 + \lambda_1)(\Delta q^e + \alpha \lambda_2 - c_u). \] This scenario implies that the expected quality improvement in the second period is relatively small relative to network externalities ($\Delta q^e < \alpha(\lambda_0 + \lambda_1)$).

**S2** \[ F \leq \Delta q^e - (\lambda_0 + \lambda_1)c_u, \quad \Delta q^e \geq (\lambda_0 + \lambda_1). \] This scenario occurs when the quality differential anticipated to be introduced by the competitor is relatively large compared to the extent of network effects.

**S3** \[ F \leq \Delta q^e - (\lambda_0 + \lambda_1)c_u, \quad \Delta q^e < (\lambda_0 + \lambda_1). \] This scenario necessarily implies that the network parameter is greater than the upgrading cost ($\alpha \geq c_u$).

In a laissez faire economy, the dominant firm compares its expected profit under the two regimes and decides whether to support compatibility or not. The next proposition summarizes the equilibrium outcome in the economy that operates under a laissez faire Competition Law. When old customers coordinate on the Pareto optimum,\footnote{If these customers coordinate on what all the other members of their class prefer, the dominant firm would be indifferent between supporting or impeding compatibility.} the proposition holds when the rival can price discriminate independently of whether new first period customers cannot postpone their purchasing decision or are willing to wait and also holds when the rival lacks the ability to price discriminate and first period customers can postpone their purchase:\footnote{See the Appendix for the dominant firm’s compatibility and price choices when consumers can postpone their purchase and the rival cannot price discriminate.}

**Proposition 2** (a) If A1-A3 and S1 or S3 hold, the dominant firm does not support com-
patibility, deterring the rival from investing and all customers purchase the product of quality \( q_1 \) in both periods. (b) If A1-A3 and S2 hold, the dominant firm supports compatibility and consumers in the second period buy the rival’s product of quality \( q_2 \).

The dominant firm’s anticipated refusal to support compatibility deters the rival from investing when the quality improvement expected to be introduced by the competitor is small relative to the extent of network effects (a). On the other hand, in (b), the expected quality differential by the competitor is large relative to the network externalities and the rival firm unambiguously invests introducing the product of quality \( q^e_2 \) in the market in the second period. In such a case, the dominant firm’s optimal strategy is to offer interoperability 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 subsection considers the problem faced by a planner that maximizes social surplus after the important version of quality \( q_1 \) is produced. He chooses whether to invest in further improving it to a product of higher expected quality \( q^e_2 \). Although consumers’ welfare is also of first order of importance, social surplus is a fuel for economic growth and will be our initial welfare measure.

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 \( q_2^e \) is sold to everyone\(^\text{34} \), social welfare becomes:

\[
W_U = \lambda_0[q_1 + \delta q_2^e + \alpha(\lambda_0 + \lambda_1) + \delta \alpha - c_u - \delta c_u] + \lambda_1[q_1 + \delta q_2^e + \alpha(\lambda_0 + \lambda_1) + \delta \alpha - c - \delta c_u] + \\
+\delta \lambda_2(q_2^e + \alpha - c) - \delta F,
\]

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 sold for two periods when \( A_1 \) and \( S_1 \) hold, (b) the product of quality \( q_2^e \) is introduced and purchased by the whole market if \( A_1 \) and \( S_2 \) hold.

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 total investment and the cost of learning how to use the new product (\( \Delta q^e < F + c_u(\lambda_0 + \lambda_1) \)). When the last inequality is reversed, social optimality is achieved when the superior product is introduced in the second period and is purchased by both the new and the old consumers.

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 Competition Law towards Intellectual Property Rights or under mandatory compatibility:

**Proposition 4** (a) If \( S_1 \) holds, an economy that mandates interoperability 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 an inefficient technological slowdown when \( S_3 \) holds.

\(^{34}\text{Because of assumption 1, the third potential case of having incompatible products is not optimal.}\)
Independently of the extent of network externalities relative to the adoption cost, an economy that mandates compatibility may lead to the inefficient introduction of the product of quality \( q_2 \) \([S1]\). A laissez faire market leads to social efficiency when network effects are relatively weak \((\alpha < c_u)\) while inefficiency may arise for relatively strong network effects \((\alpha > c_u)\) and for small values of the cost of development \((c)\). In particular, it may be socially efficient to introduce the product of quality \( q_2^e \) in the second period and nevertheless, a laissez faire market leads to technological slowdown withholding the product of quality \( q_2^e \) from the economy.

4 Sufficiently innovative quality improvements

In this section, we relax the assumption that old second period customers only buy the rival’s product when compatibility is present and after we solve for equilibrium outcomes in an economy that operates under a laissez faire Competition Law, we will investigate whether an economy that mandates compatibility or the one that allows firms to choose is preferable. Our benchmark case considers that the rival cannot price discriminate between the different customers’ classes and the new first period customers are not willing to postpone their purchase.

4.1 Market outcome

When compatibility is mandatory, the rival firm’s possible choices are either to serve the whole market or only the new second period consumers. For quality improvement satisfying \((A1)\), her optimal choice is to serve the whole market by setting an equilibrium price \( p_{21} = \Delta q + \alpha \lambda_2 - c_u \). In the first period, the market leader extracts customers’ expected total surplus by setting a price to the new and the old first period comers \((\text{from } (3) \text{ and } (4)):\)

\[
p_{11} + \delta p_{21}^e = q_1 + \delta q_2^e + \alpha (\lambda_0 + \lambda_1) + \delta \alpha - c - \delta c_u,
\]
respectively, where $p_{21} = p_{20}^e = \Delta q^e + \alpha \lambda_2 - c_u$ is the rival’s expected second period price.

When compatibility is not supported, in the second period, there are again two candidate prices for the rival: she can either charge $p_{21} = \Delta q + \alpha \lambda_2 - \alpha(\lambda_0 + \lambda_1) - c_u$ and serve the whole market or $p_{22} = \Delta q - \alpha(\lambda_0 + \lambda_1)$ and only serve the new comers. When network effects are strong ($\alpha \lambda_2 > c_u$), her optimal choice is to choose $p_{21}$ while for relatively weaker network externalities, she will decide to offer the new product to everyone when the quality improvement from its introduction is sufficiently large, satisfying the following inequality:

$$\Delta q - \alpha(\lambda_0 + \lambda_1) + \frac{1}{\lambda_0 + \lambda_1}(\alpha \lambda_2 - c_u) > 0.$$ 

In this case, the first period prices to the new and the old first period consumers are calculated using the equations:

$$p_{11} + \delta p_{21}^e = q_1 + \delta q_2^e + \alpha(\lambda_0 + \lambda_1) + \delta \alpha - c - \delta c_u,$$
$$p_{10} + \delta p_{21}^e = \Delta q + \delta \Delta q^e + \alpha \lambda_1 + \delta \alpha \lambda_2 + \delta \alpha \lambda_1 - c_u - \delta \alpha \lambda_0,$$

where $p_{21}^e = \Delta q^e + \alpha \lambda_2 - \alpha(\lambda_0 + \lambda_1) - c_u$.

In a laissez faire Competition Law, the dominant firm compares its expected profit by supplying or not allowing interoperability to the rival. The next proposition summarizes the equilibrium outcome independently of the rival’s ability to price discriminate and new customers’ (un)willingness to delay their purchasing decision:

**Proposition 5** In equilibrium, the dominant firm never supports compatibility with the smaller firm in the second period. Consumers purchase her product of quality $q_2$ in the second period.
4.2 Consumers’ Welfare maximization

We will focus on consumers’ welfare because the economies that operate under mandatory compatibility or a laissez faire Competition Law are equivalent with respect to the first welfare measure and may also lead to inefficiency. Thus, in this case our welfare measure will be consumers’ surplus and the next proposition summarizes the comparison between the economy that mandates compatibility and the one that operates under a laissez faire Competition Law when the rival cannot price discriminate.\(^{35}\)

**Proposition 6** *Consumers’ Welfare is maximised under a laissez faire Competition Law.*

*In particular, if S1 holds and A3 is relaxed, both a laissez faire market and an economy that mandates compatibility lead to the inefficient introduction of the product of quality \(q_2\) while consumers are better-off in a laissez faire economy.*

For sufficiently innovative second period products (A3 does not hold), the dominant firm does not support compatibility with his rival. This fact leads to a higher degree of competition in the second period and to lower prices, benefiting the new second period consumers.

5 Applications/ Discussion/ Future Research

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, 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

\(^{35}\)If she can price discriminate, consumers’ surplus is equivalent under compatibility and a laissez faire economy.
even if it could exclude its rival from using its network. On the other hand, the market leader does not support compatibility when the new products are sufficiently innovative.

Regarding welfare, an economy that mandates compatibility may lead to the inefficient introduction of a relatively less innovative product. We also find that when network effects are present but not particularly strong, a laissez faire market converges to social efficiency while when network effects are strong, the refusal to supply interoperability information may lead to the inefficient slowdown of technological progress. For sufficiently large expected quality improvements, a laissez faire Competition Law leads to incompatibility and fierce competitive forces benefit consumers through lower prices.

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 the European Commission, this mandate in favour of interoperability may have been harmful for society and consumers. In particular, Microsoft Office 2007 was followed by Corel’s WordPerfect Office suite in 2008. In anticipation of this, Microsoft decided not to support compatibility in the first place. If the expected quality improvement is sufficiently large and the rival firm cannot price discriminate, proposition 6 shows that new consumers are worse-off in an economy that mandates compatibility. For less innovative products, as proposition 4(a) shows, society may be better-off without the new product and the market under a laissez faire Competition policy towards Intellectual Property Rights would lead to social efficiency assuming that network effects are relatively weak.

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 without necessarily hurting or even improving consumers’ welfare. In an economy where network effects are present, this exercise is not trivial but one conclusion is certain: if network effects are not
too strong and for moderate quality improvements, an economy operating under a laissez-
faire Competition Law generates social efficiency. On top of that and for sufficiently innova-
tive new products, a laissez faire economy leads to incompatibility and maximises consumers’
surplus through lower prices when the rival lacks the ability to price discriminate between
the different consumers’ classes.

Nevertheless, there are a number of issues that are important and are not addressed in this
chapter. Firstly, a model that will test empirically our results could validate our predictions.
It would also be interesting to study the same interoperability/investment decisions from the
rival firms in the presence of stochastic demand.
6 Appendix

6.1 Period 0

We will show that there are market conditions under which the dominant firm initially invests even in the scenario that he forecasts that his product of quality $q_1$ may be followed by a competitor’s product of quality $q_2$ in the future period.

6.1.1 Compatibility

Let’s think of the scenario where the market leader decides to postpone his investment decision. Given the information he has, it is easy to see that in the first period, the firm’s optimal choice is to invest towards the product of quality $q_1$ for a relatively large quality improvement $\Delta q$. In any case, the dominant firm retains its monopoly power in the second period and thus, it can stop selling its initial version and charge its new customers a price $p_{12} = q_1 + a - c$ extracting all their surplus. Also note that the price that $\lambda_0$ customers are willing to pay is $\Delta q + \alpha \lambda_2 - c_u$, taking into consideration that old second period customers $(\lambda_0 + \lambda_1)$ coordinate on the Pareto optimal outcome. Turning our attention to the first period, the new incoming customers $(\lambda_1)$ buy the initial version $q_0$ if the total expected price $p_0 + \delta p_{11}^e$ is such that:

$$p_0 + \delta p_{11}^e = q_0 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta \alpha - c - \delta c_u,$$

where these customers expect to buy the superior product tomorrow because of its high quality improvement.

On the other hand, if he invests in the initial period ($t = 0$), his expected total profit if he forecasts that the rival will innovate tomorrow is:

$$\lambda_1[ q_1 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta \alpha(\lambda_0 + \lambda_1) - c] + \lambda_0[ \Delta q + \alpha \lambda_1 + \delta \alpha \lambda_1 - c_u(1 - \delta)] - F.$$
The dominant firm compares its expected profits from initially investing or postponing this decision to the first period. As already mentioned, the quality improvement it introduces in the market is considered important and thus, he initially invests for parameter values satisfying the condition:

\[ F - \delta F < \lambda_1(\Delta q - \delta \alpha \lambda_2 + \delta c_u) + \lambda_0(\Delta q - \delta \Delta q + \alpha \lambda_1 - \delta \alpha \lambda_2 - c_u) - \delta \lambda_2(q_1 + \alpha - c). \tag{36} \]

This inequality says that the dominant firm’s optimal choice is to invest when the benefit from a higher first period price to existing customers \((\lambda_0 + \lambda_1)\) offsets the loss from the monopoly second period profit to the new \((\lambda_2)\) customers and this happens when the quality improvement from its product is substantial and either the discount factor or the number of the incoming second period customers is relatively small.

### 6.1.2 Incompatibility

Suppose that the dominant firm initially invests into improving its product quality from a level \(q_0\) to a future level \(q_1\) and \(Pr(A)\), \(Pr(B)\) is the probability of the potential entrant subsequently coming up with a relatively important \((\Delta q^e \geq \alpha(\lambda_0 + \lambda_1))\) or less innovative \((\Delta q^e < \alpha(\lambda_0 + \lambda_1))\) idea, respectively. Thus, the dominant firm chooses to invest instead of postponing his choice to the future period if:

\[
\text{Pr}(A)[\lambda_1(q_1 + \delta q_2^e + \alpha(\lambda_0 + \lambda_1) + \delta \alpha - c - \delta c_u) + \lambda_0(\Delta q + \delta \Delta q^e + \alpha \lambda_1 + \delta \alpha \lambda_2 + \delta \alpha \lambda_1 - c_u)] + \\
+ \text{Pr}(B)[\lambda_1(q_1 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta \alpha(\lambda_0 + \lambda_1) - c) + \lambda_0(\Delta q + \alpha \lambda_1 - c_u + \delta c_u + \delta q_1 + \delta \alpha - \delta c)] - F \geq \\
\lambda_1[q_0 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta \alpha(\lambda_0 + \lambda_1) - c - \delta c_u] + \lambda_0(\delta \Delta q + \alpha \lambda_2 - c_u) + \delta \lambda_2(q_1 + \alpha - c) - \delta F.
\]

\[36\] In fact, the dominant firm always invests for a substantial improvement \(q_1\) if he cannot forecast the rival’s future innovative activity. Also note that if the first period customers are willing to postpone their purchase and the dominant firm can forecast, there is a modified inequality that needs to be satisfied for the dominant firm to initially invest with the same qualitative characteristics.
This inequality guarantees that the dominant market player initially invests into improving his product quality. Similarly to the economy that compatibility is mandatory, he will indeed decide to invest when his first period gain outweighs the second period loss.

6.2 New first period customers ($\lambda_1$) can postpone their purchase/

The rival can price discriminate

6.2.1 Compatibility

Given the first period price, $p_{11}$, new first period customers’ total expected utility if they buy $q_1$ is 

$$q_1^e + \alpha - c - p_{22}^e = q_1 + \alpha(\lambda_0 + \lambda_1) + \delta\alpha - c - \delta c_u - p_{11} - \delta p_{21}^e.$$ 

If they all postpone their purchase, they would belong to a network of size $\lambda_1 + \lambda_2$ (new second period customers) and the rival’s expected second period price can be computed by the equality:

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

or equivalently $p_{22}^e = \Delta q^e + \alpha \lambda_0$. Thus, their outside opportunity if they wait in the first period is 

$$\delta(q_2^e + a - c - p_{22}^e) = \delta[q_1 + \alpha(\lambda_1 + \lambda_2) - c]$$

and the maximum expected total price they are willing to pay to buy the product of quality $q_1$ or equivalently the dominant firm’s maximum first period price is: $p_{11} + \delta p_{21}^e = q_1 + \delta \Delta q^e + \alpha(\lambda_0 + \lambda_1) + \delta \alpha \lambda_0 - c(1 - \delta) - \delta c_u$.

6.2.2 Incompatibility

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

New first period customers’ total expected utility if they purchase $q_1$ is 

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

If they postpone their purchase, they will subsequently belong to a network of size $\lambda_1 + \lambda_2$ and their expected discounted utility is 

$$\delta(q_2^e + \alpha(\lambda_1 + \lambda_2) - c - p_{22}^{''e}),$$

where $p_{22}^{''e}$ is the expected second period price that can be computed in the following equation:

$$q_2^e + \alpha(\lambda_2 + \lambda_1) - c - p_{22}^{''e} = q_1 + \alpha - c - p_{12},$$
or equivalently \( p_{22}' = \Delta q^e - \alpha \lambda_0 \). 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
\[ p_{11} = q_1 + \alpha(\lambda_0 + \lambda_1) - \delta \alpha \lambda_2 - c(1 - \delta). \]

If \( \Delta q^e < \alpha(\lambda_0 + \lambda_1) \), the dominant firm’s optimal choice is to impede compatibility. In particular, the dominant firm compares his expected profit and he does not support compatibility if the following inequality is satisfied:
\[
\lambda_1 \alpha \lambda_2 + \lambda_2 (q_1 + \alpha - c) + \lambda_0 (\Delta q + \alpha \lambda_2 - c_u) > 0,
\]
which is always true since \( \Delta q > \Delta q^e \).

### 6.3 Old first period customers’ expected second period prices after sticking to \( q_0 \) in the first period.

#### 6.3.1 Compatibility

Old customers expect to buy \( q_0^e \) when all customers of their class either buy \( q_1 \) or stick to \( q_0 \) if:
\[
q_2^e + a - c_u - p_{20}' \geq \max\{q_0 + \alpha \lambda_0 + \alpha \lambda_1 x''_1 + \alpha \lambda_2 x''_2, \ q_1 + \alpha \lambda_0 + \alpha \lambda_1 x_1 + \alpha \lambda_2 x_2 - c_u - p_{10}'\},
\]
or equivalently: \( p_{20}' = \Delta q^e + \alpha \lambda_1 (1 - x_1) + \alpha \lambda_2 (1 - x_2), \ p_{10}' = 0 \).

#### 6.3.2 Incompatibility/ \( \Delta q^e < \alpha(\lambda_0 + \lambda_1) \)

If \( \lambda_0 \) customers stick to \( q_0 \) in the first period, there are some possibilities in the following period: if they keep \( q_0 \), their second period utility is \( q_0 + \alpha \lambda_0 x''_0 + \alpha \lambda_1 x''_1 + \alpha \lambda_2 x''_2 \) while if they buy \( q_1 \), their second period utility will be \( q_1 + \alpha - c_u - p_{10} \). Thus, they will buy the higher quality product in the second period when they make their purchasing decisions.
independently of what other $\lambda_0$ customers do if:

$$p_{10} \leq \Delta q + \alpha \lambda_1 (1 - x'_1) + \alpha \lambda_2 (1 - x'_2) - c_u.$$ 

Thus, the price expected to be set by the dominant firm in the second period is $p_{e_10} = \Delta q + \alpha \lambda_1 (1 - x'_1) + \alpha \lambda_2 (1 - x'_2) - c_u$.

### 6.3.3 Incompatibility / $\Delta q^e \geq \alpha (\lambda_0 + \lambda_1)$

$\lambda_0$ customers expect to pay a price $p''_{20}$ to purchase $q_2$ in the future period even if all other customers of their class either buy $q_1$ or stick to $q_0$ for both periods if we solve the following equation:

$$q_2 + \alpha \lambda_2 x_2 + \alpha \lambda_1 x_1 - c_u - p''_{20} =$$

$$\max\{q_1 + \alpha \lambda_0 + \alpha \lambda_2 (1 - x_2) + \alpha \lambda_1 (1 - x_1) - c_u - p''_{10}, \ q_0 + \alpha \lambda_0 + \alpha \lambda_1 x'_1 + \alpha \lambda_2 x'_2\},$$

or equivalently:

$$p''_{20} = \Delta q^e + \alpha \lambda_2 (2x_2 - 1) + \alpha \lambda_1 (2x_1 - 1) - \alpha \lambda_0$$

while their utility if they stick to $q_0$ for both periods is strictly dominated by purchasing $q_1$ tomorrow ($q_1$ is a sufficiently innovative product).

### 6.4 Market outcome / The rival cannot price discriminate / Consumers can postpone their purchase

#### 6.4.1 Compatibility

Think of new consumers in the first period ($\lambda_1$): their total expected utility if they purchase the product of quality $q_1$ is $q_1 + \delta q^e_2 + \alpha (\lambda_0 + \lambda_1) + \delta \alpha - c - \delta c_u - p_{11} - \delta p^e_{21}$ where $p^e_{21} = \Delta q^e + \alpha \lambda_2 - c_u$ (for moderately large expected quality improvements, she is better-off by choosing to serve all the customers instead of only the new second period potential consumers). If they all
postpone their purchasing decision, their total discounted expected utility is \( \delta(q^e_2 + \alpha - c - p^e_{21}) \), where \( p^e_{21} \) is the expected rival’s second period price. This price can be computed using the equation:

\[
q^e_2 + \alpha - c - p^e_{21} = q_1 + \alpha(\lambda_1 + \lambda_2) - c - p^e_{11},
\]

or equivalently \( p^e_{21} = \Delta q^e + \alpha \lambda_0 \). Thus, the maximum first period price \( p_{11} \) that these customers are willing to pay to purchase the product of quality \( q_1 \) is such that:

\[
q_1 + \delta q^e_2 + \alpha(\lambda_0 + \lambda_1) + \delta \alpha - c - \delta c_u - p_{11} - \delta p^e_{21} = \delta(q^e_2 + \alpha - c - p^e_{21})
\]

or equivalently \( p_{11} = q_1 + \alpha(\lambda_0 + \lambda_1) + \delta \alpha \lambda_0 - \delta \alpha \lambda_2 - c(1 - \delta) \). Regarding the old first period customers (\( \lambda_0 \)), they will buy \( q_1 \) if:

\[
q_1 + \delta q^e_2 + \alpha(\lambda_0 + \lambda_1) + \delta \alpha - c_u - \delta c_u - p_{10} - \delta p^e_{21} \geq q_0 + \alpha \lambda_0 + \delta \alpha + \delta q^e_2 - \delta c_u - \delta p^e_{21},
\]

where \( p^e_{21} = \Delta q^e + \alpha \lambda_2 - c_u \) and \( p^e_{21} \) is computed using the equation:

\[
q^e_2 + \alpha - c_u - p^e_{21} = q_1 + \alpha \lambda_0 - c_u - p^e_{11}
\]

or equivalently \( p^e_{21} = \Delta q^e + \alpha(\lambda_1 + \lambda_2) \). Thus, the maximum first period price that induces old customers to buy \( q_1 \) is \( p_{10} = \Delta q + \alpha \lambda_1 + \delta \alpha \lambda_1 - c_u + \delta c_u \).

### 6.4.2 Incompatibility/ A3 holds

We start with the scenario that \( \Delta q^e \geq \alpha(\lambda_0 + \lambda_1) \).

New customers’ total expected utility if they purchase the product of quality \( q_1 \) is \( q_1 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta \alpha(\lambda_0 + \lambda_1) - c - p_{11} \) while if they all wait, their outside opportunity is

\[
\delta[q^e_2 + \alpha(\lambda_1 + \lambda_2) - c - p^e_{21}],
\]

where \( p^e_{21} \) is the competitor’s expected second period price choice.
and is computed if we use the equation:

\[ q_2^e + \alpha(\lambda_1 + \lambda_2) - c - p_{21}' = q_1 + \alpha - c - p_{11} \]

or equivalently: \( p_{21}' = \Delta q^e - \alpha \lambda_0 \). Thus, the dominant firm’s optimal first period choice is \( p_{11} = q_1 + \alpha(\lambda_0 + \lambda_1) - \delta \alpha \lambda_2 - c(1 - \delta) \).

Old customers will purchase \( q_1 \) and will not stick to \( q_0 \) if:

\[ q_1 + \delta q_1 + \alpha(\lambda_0 + \lambda_1) + \delta \alpha(\lambda_0 + \lambda_1) - c_u - p_{10} \geq q_0 + \delta q_2^e + \alpha \lambda_0 + \delta \alpha \lambda_2 - \delta c_u - \delta p_{20}^{e''}, \]

where the expected price \( p_{20}^{e''} \) is computed if we use the equation

\[ q_2^e + \alpha \lambda_2 - c_u - p_{20}^{e''} = q_1 + \alpha(\lambda_0 + \lambda_1) - c_u - p_{10}, \]

or equivalently \( p_{20}^{e''} = \Delta q^e + \alpha \lambda_2 - \alpha(\lambda_0 + \lambda_1) \). Thus, the dominant firm’s first period equilibrium price choice, \( p_{10} = \Delta q + \alpha \lambda_1 - c_u(1 - \delta) \).

If \( \Delta q^e < \alpha(\lambda_0 + \lambda_1) \), the dominant firm impedes compatibility as the following inequality holds:

\[ \delta \lambda_1[q_1 + \alpha(\lambda_1 + \lambda_2) - c] + \lambda_0[c - c_u + \delta(\Delta q + \alpha \lambda_2 - c_u)] + \delta \lambda_2(q_1 + \alpha - c) > 0 \]

which always holds when \( \Delta q \geq \Delta q^e \).

Proposition 9 summarizes the dominant firm’s optimal strategy and the market equilibrium outcome.

Note that if A3 does not hold, the dominant firm is indifferent between supporting and impeding compatibility.
References


