

# PLATFORM STANDARDS, COLLUSION AND QUALITY INCENTIVES<sup>†</sup>

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## Abstract

We present the idea that quality cooperation and standardisation might raise network providers' incentives for product differentiation. As a result, the equilibrium outcome may be characterised by voluntary standardisation and maximum quality differentiation: This situation arises, if platforms compete in prices, but coordinate their quality provision, while the cost of quality provision is rather low. The result implies that firms might jointly agree to quality differences in order to offset consumers' taste for variety. Collusive qualities and standardization are socially more desirable than exclusivity with regard to investments. Nevertheless, quality competition and standardisation achieves the highest investment and maximum welfare.

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# 1 Introduction

How do quality incentives change, if competing platforms may coordinate ? How is this related to platforms' choice to standardise? By choosing whether to operate on a common standard, platforms decide on quality spillovers and to what extent network effects arise. Investment coordination then determines, whether these effects are internalised. Therefore, standard adoption and the possibility of joint quality provision influence competition and the profitability of investments.<sup>1</sup>

This article presents the idea that quality cooperation and standardisation might raise network providers' incentives for product differentiation. As a result, the equilibrium outcome may be characterised by voluntary standardisation and maximum quality differentiation: This situation arises, if platforms compete in prices, but coordinate their quality provision, while the cost of quality provision is rather low. In markets with both horizontal and vertical differentiation, this means that firms might agree to quality differences in order to offset consumer heterogeneity and let consumers agglomerate. This way, firms might jointly gain from larger network externalities. With regard to quality incentives, our results suggest a rather permissive approach towards joint research activities, if free markets are the paradigm. But still, the most efficient outcome is achieved by imposing a standard and prohibiting collusion.

To show that collusion might lead to vertical differentiation, we study competing platforms' standardisation choice and their quality investments. As Shapiro (2001) argues that quality standards are more easily used as collusive device than compatibility standards, we examine the role of collusive qualities, in particular. We adopt the concept of "fulfilled" expectations regarding market shares (Katz and Shapiro (1985)). Most importantly, we consider both horizontal and vertical differentiation: This seems characteristic for many markets, where consumers enjoy variety as well as quality.

We refer to competition between mobile network providers as our primary example. Yet, likewise the markets for operating systems like Windows and Apple's Mac OS X, its iPhone OS and Google's Android, electronic market places like Amazon, other digital media platforms or online exchanges could serve as examples: In all these markets, standard-setting

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<sup>1</sup> This question relates to the fundamental debate whether competition or the appropriability of investment rents stimulates innovation. It is a controversy that dates back to Schumpeter (1934), Schumpeter (1943) and Arrow (1962).

plays an important role, even though the complete standardisation process is rather complex.<sup>2</sup> E.g. in mobile telecommunications, the providers compete, but have established standard-setting organisations, since interoperability plays a crucial role. Therefore, one finds common transmission standards. Still, firms invest, e.g. in the field of speech and data compression or mobile access devices, to find add-ons that improve transmission or available applications. Such research is frequently conducted within joint initiatives. The EU adopts a rather lenient approach towards such joint R&D initiatives, as it aims to promote research and investments. Therefore, it has issued a block exemption from Article 81 of the EC Treaty, that aims to prevent anti-competitive collusive behaviour. In a similar vein, the new regulatory framework 2002 of the EU (Directive 2002/19/EC) recommends, but does not prescribe the use of standards to achieve interoperability for electronic communication networks.

Similar to D'Aspremont and Jaquemin (1988) or Goyal and Moraga-González (2001), our model considers that relations among firms are seldom entirely competitive or cooperative in nature. In our analysis, we link previous research on compatibility, R&D joint ventures and competition in two-sided markets. The literature on compatibility and competition frequently shows that firms choose a common standard to soften competition (Farrell and Saloner (1992), Baake and Boom (1999), Doganoglu and Wright (2006)). In these models, standardisation tends to make competition for market shares more irrelevant. Our model confirms this result, considering network provision a two-sided market.<sup>3</sup> In such markets, firms are platforms that connect two distinct groups of users each of which values the number of users of the other group. Competition in such markets is more intense than the one in one-sided markets (Armstrong (2006)). The reason are platform-specific externalities between user groups that reinforce the rivalry situation. If platforms agree on a common standard, these cross-group externalities disappear: Then, subscribers can connect to all opposite subscribers, regardless of their platform choice. Thus, if platforms standardise, they undermine their own tendency to attract subscribers by a high number of opposite subscribers.

The key point of our analysis is that platforms might collectively provide a high- and a low-performance platform. This occurs if quality provision is not too costly. Then, ver-

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<sup>2</sup> E.g. MPEG 2 standard involves 425 patents with 28 owners. Similarly, consider the various communication protocols necessary for Voice-over-IP applications or the numerous joint research activities of Verizon Wireless and its participation in respective patent pools.

<sup>3</sup> Following Armstrong and Wright (2009)

tical differentiation enables platforms to exploit increasing network effects: Under quality competition, platforms engage in a quality race. Therefore, they mutually invest without augmenting their profits. Once they coordinate, they jointly reduce investments or they create differentiated platforms. The latter becomes profitable, if gains from higher network effects exceed the costs of jointly maintaining vertical differentiation. It follows that joint quality efforts and standardisation are socially more desirable than exclusivity, where platforms always refrain from investment. Still, highest investment incentives arise with quality competition of standardised platforms, due to platforms' quality race. These findings should, in principal, continue to hold, even if we considered additional connectivity within the same market side. This is so, as long as direct network effects raise subscribers' benefits with an increasing scale.

The finding complements D'Aspremont and Jaquemin (1988)'s analysis of quality coordination and investment incentives and sets it into the context of network provision. In D'Aspremont and Jaquemin (1988)'s model, non-cooperative investment incentives are lower, and coordinated ones higher if there is standardisation or, in general, large spillovers. In our model non-cooperative investment incentives are higher with standardisation and lower, if platforms coordinate their investment. D'Aspremont and Jaquemin (1988) obtain their result, as coordination gives rise to aggregate market expansion with higher investments. We, instead obtain our results considering a fixed market size where actual surplus depends on network externalities. Platforms corroborate such externalities, when they provide higher qualities. Then, due to competition, agreeing on pronounced vertical differentiation can be most profitable. This situation occurs, if network effects exceed the joint costs of maintaining such vertical differentiation. We attain these results, as we analyse price instead of quantity competition: Here, relative performance matters and prices act as strategic complements. Collusion then enables firms to prevent head-on competition. This may give rise to asymmetric quality levels and market shares.

The literature offers several explanations for asymmetric market shares with regard to network provision: E.g. David (1985), Farrell and Saloner (1985) or Farrell and Klemperer (2007) accrue the observed asymmetries to network externalities within a dynamic setting. They explain that networks aim to establish an installed base of consumers early on, so that positive feedback effects and switching cost ensure their leading role in the future. Economides (1986), Farrell and Saloner (1992) or Hagiu (2009) instead consider incentives for differentiation that arises with consumers' valuation for variety. It is well-known that variety may come at the cost of network effects, that can be established

by standardisation (e.g. Economides (1986)). Similarly, Doganoglu and Wright (2006) analyse, how standardisation shapes competition. Therefore, they analyse how multiple platform subscriptions manipulate the equilibrium outcome. Furthermore, our analysis relates to Ma and Burgess (1993) and Wolinsky (1997). These explore, how regulated prices affect firms' quality incentives. In a similar vein, we use our results to reflect how regulated standardisation and joint research activities may affect quality provision. Closest to our idea of cooperation as an incentive for quality investment are Katz (1986) and Goyal and Moraga-González (2001). Both consider the incentives for R&D cooperation, assuming it might reduce research cost. Katz (1986) here examines different cost and profit sharing rules and compares the R&D outcome to the one of a monopolistic market. Goyal and Moraga-González (2001), instead, study network formation that results from sharing of knowledge about a cost-reducing technology.

In contrast with this literature, we study network competition within a simple static framework, where network externalities outweigh consumers' taste for variety. We do not consider monopoly reactions, nor do we look at cost reductions. Our main interest lies in network externalities: We explore how cooperation influences them. In our model, network effects rise with the number of platform subscriptions and provided quality levels. Thus, instead of lowering research costs, qualities significantly affect consumers' valuation. Due to price competition, quality investments increase platforms' profits with vertical differentiation only.

To study the problem we proceed as follows: Section 2 contains the basic setup, Section 3 looks at competition for subscribers in case of standardised and exclusive platforms, Section 4 deals with the choice of quality investments, Section 5 looks at the compatibility decision and Section 6 concludes. All formal proofs are relegated to the Appendix.

## 2 The Model

We study a market which involves two groups of agents. These agents interact via “platforms” where one group's benefit from joining a platform depends on the size of the other group it can connect to. Such a market is commonly referred to as “two-sided”. To analyse competition in such a market, let us consider two platforms  $a = A, B$  which serve as intermediaries between the two different types of agents  $i = 1, 2$ .

*Agents:*

On each platform side, there is a continuum of heterogeneous agents  $i$  with a total mass of 1. These agents are uniformly distributed over a Hotelling line with location  $x_i \in [0, 1]$ , where platform  $A$  is situated at 0 and  $B$  at 1. The agents join one of the platforms for a fixed subscription fee  $p_i^a$  which enables the two different groups to interact. Therefore, if an agent subscribes to platform  $A$ , total utility amounts to the benefit  $u_i^A$  reduced by the subscription fee and 'transport cost'  $tx_i$ , i.e.

$$U_i^A = u_i^A - p_i^A - tx_i \quad (1)$$

and likewise

$$U_i^B = u_i^B - p_i^B - t(1 - x_i),$$

if an agent  $i$  subscribes to platform  $B$ . Parameter  $t$  here reflects consumers' individual preferences for a certain platform, including costs of learning about the new service and signing up for it.<sup>4</sup> Benefits  $u_i^a$ , derived from possible transactions with the other type of agents, are contingent on whether platforms' agreed to use a common standard or not and on transaction qualities  $q^a$ . We restrict attention to positive network effects and non-drastic innovations. Therefore, we assume  $q^a \in [\underline{q}, \bar{q}]$  where  $0 < \underline{q} < \bar{q}$ , where investing in  $\bar{q}$  cannot induce exclusion. If, then, platforms decide to operate exclusively, benefits are equal to

$$u_i^{a,E}(q^a, N_j^a) = v_0 + 2q^a N_j^a. \quad (2)$$

By this, benefits are increasing in platform  $a$ 's *expected* number of opposite users  $N_j^a$  and the quality  $q^a$  the platform provides. We add positive baseline utility  $v_0$  to ensure full participation of potential subscribers, assuming that it is sufficiently large.

For the case of standardised platforms, we specify net benefits of an agent  $i$  at platform  $a$  by

$$u_i^{a,S}(q^A, q^B, N_j^a) = v_0 + 2q^a N_j^a + (q^A + q^B)(1 - N_j^a). \quad (3)$$

Thus, the main difference to the case of exclusivity is that user  $i$  of platform  $a$  can connect to both platforms' opposite subscribers, respectively platform  $a$ 's *expected* number  $N_j^a$  and the rival's *expected* number  $N_j^b = 1 - N_j^a$ . Referring to the stochastic nature of Internet traffic over multiple networks, we assume that transaction quality corresponds to the average quality of platforms involved. That is, transactions are characterised by a platform's own quality in case users connect on the same, and the sum of both platforms'

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<sup>4</sup> Another interpretation is individual preferences due to the design of a service which makes it differing useful on a regular handset, an iPhone or a Laptop.

qualities in case users connect over the two platforms.

*Platforms:*

Competing for subscribers involves several decisions of the two platforms: In a first step, they have to agree whether to operate on a common standard or not: Choosing a common standard ensures the interoperability of platforms. After that, they decide on their quality  $q^a$ . But before fixing their actual level of quality investment, the two platforms can consider coordination. Providing quality incurs cost  $C(q^a) = \gamma (q^a - \underline{q})^2$ . Under this assumption, quality cost  $C(q^a)$  is continuous, strictly increasing and convex in  $q^a$  and amounts to zero if only the minimum quality  $\underline{q}$  is supplied. We presume any other cost to be a fixed setup cost and normalise it to zero.<sup>5</sup> Finally, in the market stage, platforms simultaneously set the subscription fees  $p_i^a$  for their user groups  $i$ . Note that we abstract from capacity concerns, as this is not the main concern of our analysis.

Given these decisions and the cost of quality provision, a platform  $a$ 's profit function can be written as

$$\Pi^a = p_1^a n_1^a + p_2^a n_2^a - C(q^a). \quad (4)$$

In addition, we maintain the following assumptions throughout our analysis:

**Assumption 1.**  $t < \frac{2}{3}v_0$ .

This ensures all agents subscribe to one platform in equilibrium. Further, we suppose

**Assumption 2.**  $t > 2\bar{q}$

and

**Assumption 3.**  $t \geq 1$ .

Under these assumptions, platforms' profits are always strictly concave in prices.<sup>6</sup> Therefore, the equilibrium in the market stage is unique. Finally, we restrict attention to

**Assumption 4.**  $0 < \gamma < 16/9t \equiv \bar{\gamma}$ .

Then, both platforms find market activity profitable in equilibrium and their participation is ensured.

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<sup>5</sup> This seems adequate since we refer to interconnection via the Internet. Here, it is said that interfaces and other interconnection facilities involve initial setup costs, but no other traffic-dependent cost in the absence of capacity constraints, see also Atkinson and Barnekov (2004).

<sup>6</sup> Strictly speaking, Assumption 2 ensures that  $t^2 > (q^A + q^B)^2$  holds for all quality levels, see Proof of Proposition 2 in the Appendix.

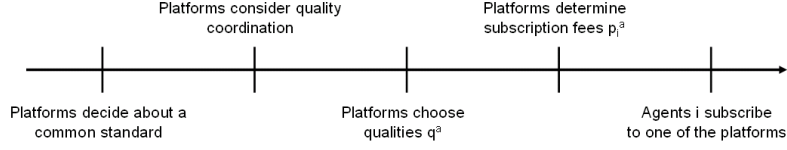


Figure 1: The Timing of the Game

The time structure of the model is summarised in Figure 1: Firstly, platforms choose whether to conform to a common standard or not. Then, platforms decide whether to cooperate in terms of quality investments. Subsequently, simultaneous quality investments take place. Finally, platforms determine subscription fees and agents choose which platform to subscribe to given their expectations about the number of subscribers on the opposite side will be fulfilled, formally  $n_i^a = N_i^a$ .<sup>7</sup>

We will determine the subgame perfect Nash equilibria of the game by solving it backwards.

### 3 Market shares and prices

Market shares are determined by the indifference condition  $U_i^A = U_i^B$ . This identifies the location of marginal consumers  $x_i$ , indifferent between joining network  $A$  or  $B$ , for each market side  $i = 1, 2$ . Considering  $x_i = n_i^a$ , this yields

$$n_i^a = \frac{1}{2} + \frac{u_i^a - u_i^b + p_i^b - p_i^a}{2t} \quad (5)$$

given a fixed market size  $n_i^A + n_i^B = 1$ , so that  $n_i^B = 1 - n_i^A$ . Note that we define platform  $A$ 's market share  $n_i^A$  of agents  $i$  as  $x_i \equiv n_i^A$ . Platforms consider (5) when they maximise their profits, formally,

$$\max_{p_1^a, p_2^a} \pi^a = p_1^a n_1^a + p_2^a n_2^a - C(q^a).$$

We look at simultaneous price reactions of the two platforms to obtain equilibrium price levels. Since we take platforms' decision about a common standard as given, we distinguish

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<sup>7</sup> See Katz and Shapiro (1985).



between the case of standardisation and exclusivity:

### 3.1 Standardisation

In case of a common standard, users subscribe to one of the platforms according to (3) combined with (5). We presume fulfilled expectations about market shares with  $N_i^a = n_i^a$  and resolve the ensuing conditions to describe platforms' market shares as

$$n_i^{A,S} \left( t, q^A, q^B, p_i^{A,S}, p_i^{B,S} \right) = \frac{1}{2} + \frac{q^A - q^B + p_i^{B,S} - p_i^{A,S}}{2t} \quad \text{and} \quad (6)$$

$$n_i^{B,S} \left( t, q^A, q^B, p_i^{A,S}, p_i^{B,S} \right) = \frac{1}{2} + \frac{q^B - q^A + p_i^{A,S} - p_i^{B,S}}{2t}. \quad (7)$$

By (6) and (7) the following is immediate:

**Lemma 1.** *Given a common standard, each platform's market shares are independent of the opposite side's prices. That is, competition for  $i$ -type users depends on prices  $p_i^A$  and  $p_i^B$  only.*

Observe that in case of a common standard, opposite subscribers can connect to each other no matter which platform they joined: Hence, network effects across a platform are undermined by standardisation and therefore, price competition in market 1 will not influence competition in market 2 or vice versa. Platforms' first-order conditions, correspondingly, are

$$\frac{\partial \pi^{a,S}}{\partial p_i^{a,S}} = n_i^{a,S} + p_i^{a,S} \frac{\partial n_i^{a,S}}{\partial p_i^{a,S}} = 0 \quad (8)$$

for  $i = 1, 2$  and  $a = A, B$  and generate two sets of two simultaneous conditions. These characterise equilibrium prices. Inserting these into (6) and (7) yields equilibrium market shares. Proposition 1 summarises the results:

**Proposition 1.** *In case of a common standard a unique equilibrium in the market stage exists. For  $i = 1, 2$ , prices are given by*

$$p_i^{A,S} = t + \frac{1}{3} \Delta_q \quad \text{and} \quad p_i^{B,S} = t - \frac{1}{3} \Delta_q \quad (9)$$

and market shares by

$$n_i^{A,S} = \frac{1}{2} + \frac{1}{6t} \Delta_q \quad \text{and} \quad n_i^{B,S} = \frac{1}{2} - \frac{1}{6t} \Delta_q. \quad (10)$$

Here, qualities are expressed by their relative value, i.e.  $\Delta_q = q^A - q^B$ . Market shares and prices of a platform  $A$  are increasing in  $\Delta_q$ , those of platform  $B$  in  $-\Delta_q$ . Indeed, platforms only gain from higher qualities by outperforming their rival. This is a well-known feature of price competition in regular one-sided markets. Interestingly, even though we analyse competition in a two-sided market, the number of a platform's opposite subscribers does not affect the outcome. The reason is that - in case of standardisation - a platform's subscribers can always connect to all opposite subscribers. Then, as stated in Lemma 1, subscribers' network benefits arise regardless of its market shares on the other platform side.

### 3.2 Exclusivity

In case of exclusivity, conditions (2) and (5) describe which platform users subscribe to. Similar to the previous case, we presume fulfilled expectations and solve the conditions for platforms' market shares  $n_i^{A,E}$  and  $n_i^{B,E}$ . We get

$$n_i^{A,E} = \frac{t^2}{T} \left( \frac{1}{2} + \frac{\Delta_q + p_i^{B,E} - p_i^{A,E}}{2t} \right) + \frac{1}{2T} (q^A + q^B) \left( -2q^B + p_j^{B,E} - p_j^{A,E} \right) \quad (11)$$

and

$$n_i^{B,E} = \frac{t^2}{T} \left( \frac{1}{2} + \frac{-\Delta_q + p_i^{A,E} - p_i^{B,E}}{2t} \right) + \frac{1}{2T} (q^A + q^B) \left( -2q^A + p_j^{A,E} - p_j^{B,E} \right) \quad (12)$$

with  $T = t^2 - (q^A + q^B)^2$  for  $i, j = 1, 2$  and  $i \neq j$ . By this, it immediately follows:

**Lemma 2.** *Given exclusivity, each platform's market shares are determined by subscription prices of both platform sides. That is, a platform's market share of  $i$ -type users depends on all four prices  $p_i^A$  and  $p_i^B$ .*

To see the intuition for Lemma 2, note that subscribers can only connect to opposite members of *their* platform in case of exclusivity. Therefore, subscribers obtain higher network benefits the larger their platform's market share of opposite users. This leads to interdependent competition for the two groups of subscribers. As a result, subscription prices of both market sides affect the equilibrium outcome. This also becomes obvious by looking at the platforms' price reaction functions, a system of four simultaneous conditions:

$$n_i^{A,E} + p_i^{A,E} \frac{\partial n_i^{A,E}}{\partial p_i^{A,E}} + p_j^{A,E} \frac{\partial n_j^{A,E}}{\partial p_i^{A,E}} = 0 \quad \text{and} \quad (13)$$

$$n_i^{B,E} + p_i^{B,E} \frac{\partial n_i^{B,E}}{\partial p_i^{B,E}} + p_j^{B,E} \frac{\partial n_j^{B,E}}{\partial p_i^{B,E}} = 0 \quad (14)$$

with  $i, j = 1, 2$  and  $i \neq j$ . By solving these and using (11) and (12), we find:

**Proposition 2.** *Given exclusivity, a unique equilibrium exists in the market stage. Prices are given by*

$$p_i^{A,E} = t - \frac{2}{3}(q^A + 2q^B) \quad \text{and} \quad p_i^{B,E} = t - \frac{2}{3}(2q^A + q^B) \quad (15)$$

and market shares by

$$n_i^{A,E} = \frac{t^2}{T} \left( \frac{1}{2} + \frac{\Delta_q}{6t} \right) - \frac{1}{3T} (q^A + q^B) (q^A + 2q^B), \quad (16)$$

$$n_i^{B,E} = \frac{t^2}{T} \left( \frac{1}{2} - \frac{\Delta_q}{6t} \right) - \frac{1}{3T} (q^A + q^B) (2q^A + q^B) \quad (17)$$

with  $T = t^2 - (q^A + q^B)^2$  and  $i = 1, 2$ .

Thus, quality differences  $\Delta_q$  and absolute quality levels  $q^a$  affect the market outcome in case of exclusivity. Equilibrium prices, here, decrease when either platform provides higher quality. For market shares, this is not clear at first sight because two opposite effects appear according to (16) and (17). The first one, represented by the first expression on the RHS of (16) or (17), captures platforms' direct competition for type  $i$ -subscribers. Due to it, market shares increase when a platform provides higher quality than its rival. On the contrary, the second term, displays a negative impact of higher platforms' qualities on market shares. It arises because competition for both subscriber types is interdependent as stated in Lemma 2. This generates feedback effects between platform sides. It leads to intensified competition when there are higher qualities which induce higher network benefits. Considering Assumptions 1 to 4 we compare the size of these two effects and find that feedback quality effects dominate direct ones. Therefore, higher qualities, in case of exclusivity, diminish market shares. Since feedback effects induce fiercer competition, higher qualities likewise imply lower prices.

From comparing Proposition 1 and 2 we immediately infer that price competition changes when platforms decide to standardise or not:

**Corollary 1.** *For given qualities, price competition in case of exclusivity is stronger than in case of standardisation, therefore,  $p_i^{a,E} < p_i^{a,S}$  for  $i = 1, 2$ .*

Similar to Farrell and Saloner (1992) Corollary 1 implies that standardisation can serve as a means to soften competition. Here, platforms' standardisation decision changes the competitive mode. Observe that this comes with the changing interdependency of a platform's markets as stated in Lemma 1 and 2.

## 4 Quality Investment

We now examine platforms' incentives to invest in quality. As we follow D'Aspremont and Jaquemin (1988)'s approach, platforms can choose to coordinate their quality levels before they invest. Note that price and quality competition are linked to each other because qualities are chosen before prices are set.<sup>8</sup>

### 4.1 Uncoordinated quality investment and standardisation

When platforms compete in qualities, they invest to maximise their profits, taking their rival's quality choice as given. Mutual best responses, then, determine equilibrium qualities. Considering our results stated in Proposition 1, quality investment of a standardised platform  $a$  amounts to

$$q^{a*} = \arg \max_{q^a} \pi^a(t, \gamma, q^a, q^{b*}) = \frac{1}{9t} (3t + q^a - q^b)^2 - \gamma (q^a)^2 \quad (18)$$

with  $a, b = A, B$  and  $a \neq b$ . Since a platform's profit increases when it provides a higher quality than its rival, a quality race occurs:

**Lemma 3.** *There exists a  $\bar{\gamma}^*$  such that equilibrium qualities are given by  $q^{A,S*} = q^{B,S*} = \bar{q}$  if  $\gamma \leq \bar{\gamma}^*$ , and by  $q^{A,S*} = q^{B,S*} = 1/(3\gamma)$  if  $\gamma > \bar{\gamma}^*$ , when standardised platforms compete in qualities.*

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<sup>8</sup> See also Farrell and Saloner (1988). One could also analyse whether platforms would individually make an effort to achieve compatibility ex-post. See Bender and Schmidt (2007) for an example where such issue matters.

Competition for subscribers, therefore, triggers quality investment subject to its cost. If the cost of quality provision is relatively small, i.e.  $\gamma \leq \bar{\gamma}^*$ , where  $\bar{\gamma}^* \equiv 1/3\bar{q}$ , maximum quality levels arise in equilibrium. If, however, cost is relatively high, platforms invest until their marginal revenues equal their marginal costs. This solution represents a classical prisoners' dilemma where lack of coordination induces suboptimal outcomes for platforms.<sup>9</sup>

## 4.2 Uncoordinated quality investment and exclusivity

In case of exclusivity competition for both types of subscribers is interdependent. A platform  $a$ 's profit depends on both platforms' qualities according to

$$\pi^{a,E} = \frac{2}{T} \left[ t - \frac{2}{3}(q^a + 2q^b) \right] \left[ \frac{t^2}{2} + \frac{t(q^a - q^b)}{6} - \frac{1}{3}(q^a + q^b)(2q^b + q^a) \right] - \gamma(q^a)^2 \quad (19)$$

which combines (4) with results from Proposition 2. Lemma 4 describes the equilibrium quality choices.

**Lemma 4.** *There is a unique symmetric equilibrium when exclusive platforms compete in qualities. Platforms provide  $q^{A,E^*} = q^{B,E^*} = \underline{q}$ .*

Hence, when platforms operate exclusively, quality competition does not create investment incentives. Quite to the contrary, platforms withdraw from investment as much as possible. This behaviour is induced by the way platforms compete for subscribers. Here, according to Proposition 2, higher qualities will decrease a platform's profit at any cost level. The reason is that higher qualities intensify competition and lower prices. Therefore, in order to receive higher profits, platforms refrain from investment. In other words, lower investment serves to soften competition.<sup>10</sup>

In sum, Lemma 3 and 4 allow us to compare platforms' investment incentives, given their decision about a common standard and uncoordinated investment. Proposition 3 summarises our findings:

**Proposition 3.** *Without collusion, standardised platforms invest more in qualities than exclusive ones, i.e.  $q^{a,S^*} > q^{a,E^*}$  for  $a = A, B$ .*

<sup>9</sup> Given symmetry, profit maximisation becomes a question of cost minimisation leading to minimum quality levels.

<sup>10</sup> In fact, if we permitted negative qualities such as conscious delay or interruption of transmission, the equilibrium qualities would amount to  $q^{A,E} = q^{B,E} = -\frac{1}{6\gamma}$ . In other words, platforms would aim to reduce dominant indirect network externalities to a certain extent.

As noted before, platforms' investment incentives build on the competitive situation in the market stage. Since higher qualities might raise a platform's profit in case of standardisation, it invests. On the contrary, a platform does not invest in case of exclusivity since higher qualities unambiguously reduce profits. Our results, therefore, contrast D'Aspremont and Jaquemin (1988)'s. They claim that investment incentives are larger the lower spillovers from investment. In our model this interplay between spillovers and investment is reversed: Investment incentives are the highest the largest the spillovers, which happens in case of a common standard.

### 4.3 Coordinated quality investment and standardisation

When platforms coordinate their investments, they choose quality levels to maximise joint profits. Given a common standard, qualities are chosen according to

$$q_c^{a*} = \arg \max_{q^a, q^b} \pi_c^S(t, \gamma, q^a, q^b) = \pi^{A,S} + \pi^{B,S}$$

considering each platform  $a$ 's individual profit as given in (18). Note that the joint profit function  $\pi_c^S$  is not concave in qualities for all cost parameters  $\gamma$  so that the usual first-order approach is inappropriate. Instead, following Bester and Petrakis (1993), we determine the conditions under which a platform gains from providing higher quality by comparing profits globally. Let us use

$$\bar{\gamma}_{AB} \equiv 2(\bar{q} - \underline{q}) / 9t\bar{q} < 2/9t$$

to describe platforms' quality investments as a result of collusion:

**Lemma 5.** *Given a common standard, platforms collude to achieve maximal vertical differentiation with  $q_c^{a,S*} = \underline{q}$  and  $q_c^{b,S*} = \bar{q}$  if  $\gamma < \bar{\gamma}_{AB}$ . If, however,  $\gamma \geq \bar{\gamma}_{AB}$ , collusion leads to minimum quality levels, i.e.  $q_c^{A,S*} = q_c^{B,S*} = \underline{q}$  for  $a, b = A, B$  and  $a \neq b$ .*

Here, for  $\gamma \geq \bar{\gamma}_{AB}$ , providing higher quality is always too costly to generate any profits. Therefore, platforms mutually provide baseline quality  $\underline{q}$ , when they coordinate their investments. This incidentally resolves the platforms' prisoners' dilemma which occurs for uncoordinated investments. Conversely, the outcome for  $\gamma < \bar{\gamma}_{AB}$  is induced by two different profitability concerns: First of all, taking the competitor's quality as given, marginal returns increase, when a platform provides higher quality. Second, providing higher quality is less profitable the higher the competitor's, since qualities interact as strategic substitutes. In this situation, coordination allows platforms to consider both the

individual and the strategic effect of supplying higher quality. As a result, they agree on one platform of superior and one of inferior quality. This way, the majority of subscribers locates at the platform which provides  $\bar{q}$  and network effects are maximised. These can be extracted via subscription prices, and therefore, platforms jointly achieve higher profits than in case of quality competition.

#### 4.4 Coordinated investment and exclusivity

Also in case of exclusivity, platforms consider joint profits  $\pi_c^E = \pi^{A,E} + \pi^{B,E}$  when they coordinate their quality investments. Yet, under exclusivity, investment incentives do not alter with possible collusion:

**Lemma 6.** *Exclusive platforms refrain from quality investment, s.t.  $q_c^{A,E^*} = q_c^{B,E^*} = \underline{q}$  if they coordinate their investment activities.*

Clearly, this result arises because increasing qualities substantially intensify competition. To compensate for that, platforms maintain baseline qualities only. This serves to lessen competition.

Proposition 4 summarises platforms' investment incentives if they can coordinate quality levels:

**Proposition 4.** *When collusion is possible, platforms jointly provide higher qualities if  $\gamma < \bar{\gamma}_{AB}$ , i.e.  $q_c^{A,S^*} + q_c^{B,S^*} > q_c^{A,E^*} + q_c^{B,E^*}$ . If, however,  $\gamma \geq \bar{\gamma}_{AB}$ , platforms always provide baseline quality  $\underline{q}$  only.*

Coordination, therefore, prevents unprofitable investments from a platform's perspective. Nevertheless, coordinated supply of qualities does not necessarily result in mutual low quality provision: With rather low cost, i.e.  $\gamma < \bar{\gamma}_{AB}$ , exploiting network effects leads to highest joint profits. Therefore, asymmetric quality investments arise to establish asymmetric platforms.

## 5 Private and social incentives for standardisation

We now examine whether platforms prefer a common standard or exclusivity by comparing profits of potential market outcomes.<sup>11</sup> Indeed, incentive considerations of Lemma 5 and

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<sup>11</sup> It is clear that if platforms, in an alternative setup, agreed on interconnection after quality but before price competition, standardisation would always arise. It is a consequence of softer competition and the prospective of higher returns in such a situation.

Corollary 1 imply that platforms always choose a common standard if they can collude in qualities. To gain further insights, let us also look at the profits which result from uncoordinated quality provision. First, suppose a situation of relatively low quality cost

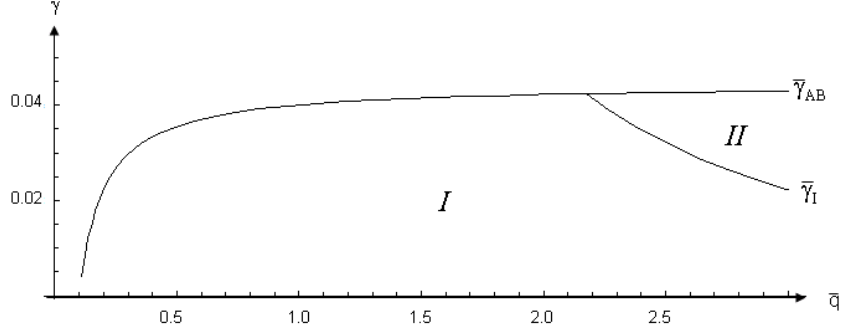


Figure 2: Profit outcomes, given  $\underline{q} = 0.1$  and  $t = 5$

where platforms vertically differentiate to maximise their profits:

**Proposition 5.** *There exists a  $\bar{\gamma}_I(\underline{q}, \bar{q})$  with  $0 < \bar{\gamma}_I < \bar{\gamma}_{AB}$  such that, with  $a = A, B$ , platforms' equilibrium profits under their different cooperative agreements can be ranked as follows:*

(i) *If  $\gamma < \bar{\gamma}_I$ , then  $\pi_c^S > \sum_a \pi^{a,S} > \pi_c^E = \sum_a \pi^{a,E}$ .*

(ii) *If  $\gamma \geq \bar{\gamma}_I$ , then  $\pi_c^S > \pi_c^E = \sum_a \pi^{a,E} > \sum_a \pi^{a,S}$ .*

*Thus, platforms agree on a common standard, as long as they can coordinate their quality provision.*

Figure 2 illustrates Proposition 5 for a numerical example by showing how profits of market outcomes depend on cost parameter  $\gamma$  and maximum quality  $\bar{q}$ , given baseline quality  $\underline{q}$ . The borderline between regions *I* and *II* is defined by  $\bar{\gamma}_I(\underline{q}, \bar{q})$ .<sup>12</sup> Thus, in region *I*, the gains from higher prices when platforms standardise - in spite of excessive quality investment - are higher than the ones from saving quality cost when platforms operate exclusively. Just the opposite applies in region *II*, where the lowest and highest possible quality differ more significantly. Here, platforms prefer exclusive operation to quality competition under a common standard.

Most importantly, platforms always prefer a common standard to exclusivity if they can

<sup>12</sup> For an explicit expression of  $\bar{\gamma}_I(\underline{q}, \bar{q})$  and all other borderlines in the following, see the Appendix.



coordinate their quality investment. This is so because collusion under a common standard enables platforms to reap profits from investment provided that it is not too costly: By choosing a common standard, platforms sustain the profitability of quality investments in case a platform outperforms its rival. Coordination, in such a situation, prevents plat-

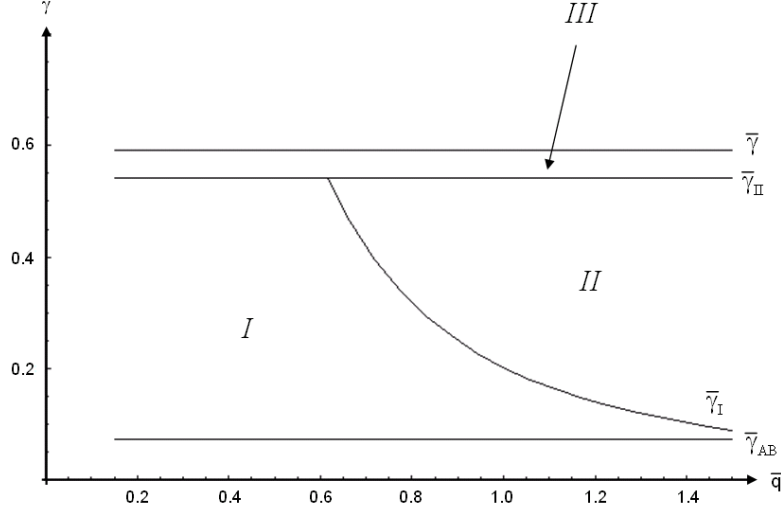


Figure 3: Profit outcomes, given  $\underline{q} = 0.1$  and  $t = 5$

forms to engage in quality competition. Instead, they abstain from investment if it is too costly, or they invest to exploit increasing network effects if cost of quality provision is rather low. Next, we study profit outcomes in case of relatively high quality cost where platforms jointly agree to refrain from investment:

**Proposition 6.** *There exist a  $\bar{\gamma}_I(\underline{q}, \bar{q})$  and  $\bar{\gamma}_{II}(\underline{q}, \bar{q})$  with  $\bar{\gamma}_{AB} < \bar{\gamma}_I < \bar{\gamma}_{II} < 16/9t$  such that, with  $a = A, B$ , platforms' equilibrium profits under their different cooperative agreements can be ranked as follows:*

- (i) *If  $\gamma < \bar{\gamma}_I$ , then  $\pi_c^S \geq \sum_a \pi^{a,S} > \pi_c^E = \sum_a \pi^{a,E}$ .*
- (ii) *If  $\bar{\gamma}_I \leq \gamma < \bar{\gamma}_{II}$ , then  $\pi_c^S > \pi_c^E = \sum_a \pi^{a,E} > \sum_a \pi^{a,S}$ .*
- (iii) *If  $\gamma \geq \bar{\gamma}_{II}$ , then  $\pi_c^S \geq \sum_a \pi^{a,S} > \pi_c^E = \sum_a \pi^{a,E}$ .*

*Thus, platforms choose a common standard as long as they can coordinate their quality provision.*

Still, platforms choose a common standard if they can collude in qualities according to Lemma 5 and Corollary 1. But in contrast to the previous case, platforms jointly refrain from investment since providing higher quality is always unprofitable. Figure 3 illustrates whether exclusivity or standardisation is preferred in case of quality competition. For parameter values  $\gamma$  and  $\bar{q}$  that lie in region *I* and *III*, standardisation where platforms compete in qualities turns out to be more profitable than exclusivity. It is the result of more intense competition in case of exclusivity. In region *II*, on the contrary, exclusivity yields higher profits than quality competition of standardised platforms. Here, due to significant quality differences, the cost of providing maximum quality offsets the gains from softer competition compared to the case of exclusivity.

We further evaluate welfare for the various potential outcomes. This allows us to find out whether private and social incentives for a common standard diverge. Note that for our specific setup, welfare reduces to subscribers' network benefits less transportation and quality cost. Then, given that in our model market size is fixed, welfare indicates whether quality provision generates additional surplus. We come to the following conclusion:

**Proposition 7.** *Given the platforms' different cooperative agreements, welfare can be ranked as follows:  $W^S \geq W_c^S > W^E$ , i.e. quality competition of standardised platforms always generates the highest and exclusivity the least social surplus.*

Hence, the socially most desirable situation is aligned with the highest investment incentives, which arise in case of quality competition between standardised platforms. Note also that a common standard is both privately and socially desirable according to Proposition 6 and 7. But in this regard, the effects of a common standard cannot be disentangled from the possibility of collusive investments: From a social point of view, quality competition between standardised platforms is optimal. Yet, platforms find a common standard only desirable when they can coordinate their quality provision. Even though coordination between standardised platforms does not lead to maximum welfare, it creates higher social benefits than exclusivity due to additional network benefits.

## 6 Conclusion

We examined how platform interoperability and subsequent quality coordination affect platforms' investment incentives. Here, we found, that quality collusion may induce standardisation and investment incentives, if cost of quality provision is rather low. The reason is, that collusion enables platforms to exploit network effects by maintaining vertically

differentiated platforms, instead of entering a quality race. Standardisation and coordinated qualities become socially more desirable than exclusivity in such a situation. But nevertheless, standardisation and quality competition induce highest investments and, therefore, highest welfare.

Our analysis was motivated by the observation that firms' research takes place in various stages and therefore, offers, various possibilities of cooperation. As an example, we considered mobile network providers. In practice, these adhere to the same transmission standard, but still invest to find add-ons that further improve transmission or available applications. In this context, our findings suggest that regulating standardisation or quality coordination will affect quality incentives: A permissive antitrust treatment of joint R&D initiatives might induce standardisation and some investments; but still, imposing a standard and prohibiting collusion - and therefore rigorous intervention - would achieve the welfare maximising outcome.

The article focusses on effects and incentives to collude within a static framework. We referred to interoperability considering the two polar cases exclusivity and standardisation. Previous research has argued that, in the real world, varying degrees of compatibility exist. Likewise, assuming agents' full participation served to simplify our framework and sufficed to make our point. Including such extensions might lead to other equilibrium constellations. A full analysis of these issues is left to future research.

## 7 Appendix

### Proof of Proposition 1:

Utilities of subscribers in case of standardised platforms can be described as

$$\begin{aligned} U_i^{A,S} &= v_0 + 2q^A N_j^{A,S} + (q^A + q^B)(1 - N_j^{A,S}) - p_i^{A,S} - tx_i, \\ U_i^{B,S} &= v_0 + 2q^B N_j^{B,S} + (q^A + q^B)(1 - N_j^{B,S}) - p_i^{B,S} - t(1 - x_i) \end{aligned}$$

with  $N_i^{B,S} = 1 - N_i^{A,S}$ . Market shares are determined by identifying the marginal consumer  $i$  with  $i = 1, 2$  who is indifferent between network  $A$  and  $B$ , i.e.  $U_i^{A,S} = U_i^{B,S}$ . Presuming  $x_i = n_1^A$ , this yields conditions as described in (5). Then, under fulfilled expectations, s.t.  $n_i^a = N_i^a$ , solving these conditions simultaneously leads to

$$\begin{aligned} n_i^{A,S} \left( q^A, q^B, p_i^{A,S}, p_i^{B,S} \right) &= \frac{1}{2} + \frac{q^A - q^B + p_i^{B,S} - p_i^{A,S}}{2t}, \\ n_i^{B,S} \left( q^A, q^B, p_i^{A,S}, p_i^{B,S} \right) &= \frac{1}{2} + \frac{q^B - q^A + p_i^{A,S} - p_i^{B,S}}{2t} \end{aligned}$$

also given in (6) and (7). These results have to be taken into account when platforms set prices. The platforms' profit considerations can be written as

$$\max_{p_1^{a,S}, p_2^{a,S}} \pi^{a,S} = p_1^{a,S} n_1^{a,S} + p_2^{a,S} n_2^{a,S} - C(q^a)$$

for  $a = A, B$ . Then, the first-order conditions with respect to prices  $p_i^{A,S}$  and  $p_i^{B,S}$  can be stated as

$$\begin{aligned} \frac{1}{2} + \frac{q^A - q^B + p_i^{B,S} - 2p_i^{A,S}}{2t} &= 0 \quad \text{and} \\ \frac{1}{2} + \frac{q^B - q^A + p_i^{A,S} - 2p_i^{B,S}}{2t} &= 0. \end{aligned}$$

Solving simultaneously the two systems of two first-order-conditions results in equilibrium prices

$$\begin{aligned} p_i^{A,S} &= t_i + \frac{1}{3} (q^A - q^B), \\ p_i^{B,S} &= t_i + \frac{1}{3} (q^B - q^A) \end{aligned}$$

as given in (9). Inserting these values into (6) and (7) returns market shares as given in (10), i.e.

$$\begin{aligned} n_i^{A,S} &= \frac{1}{2} + \frac{1}{6t} (q^A - q^B), \\ n_i^{B,S} &= \frac{1}{2} + \frac{1}{6t} (q^B - q^A). \end{aligned}$$

q.e.d

### Proof of Proposition 2:

If platforms operate exclusively, agents' utilities are given by (1) and (2). Market shares are determined by the indifference condition  $U_i^{A,E} = U_i^{B,E}$ . Analogue to the calculus for Proposition 1, we presume  $x_i = n_i^A$  and fulfilled expectations. Then market shares can be expressed as

$$\begin{aligned} n_i^{A,E} &= \frac{t^2}{T} \left[ \frac{1}{2} + \frac{q^A - q^B + p_i^{B,E} - p_i^{A,E}}{2t} \right] + \frac{1}{2T} (q^A + q^B) \left( -2q^B + p_j^{B,E} - p_j^{A,E} \right), \\ n_i^{B,E} &= \frac{t^2}{T} \left[ \frac{1}{2} + \frac{q^B - q^A + p_i^{A,E} - p_i^{B,E}}{2t} \right] + \frac{1}{2T} (q^A + q^B) \left( -2q^A + p_j^{A,E} - p_j^{B,E} \right) \end{aligned}$$

with  $T = t^2 - (q^A + q^B)^2$  and  $i, j = 1, 2, i \neq j$  according to (13) and (14). Profits

$$\pi^{A,E} = p_1^{A,E} n_1^{A,E} + p_2^{A,E} n_2^{A,E} - \gamma(q^A)^2 \quad \text{and} \quad (20)$$

$$\pi^{B,E} = p_1^{B,E} n_1^{B,E} + p_2^{B,E} n_2^{B,E} - \gamma(q^B)^2 \quad (21)$$

are considered to derive platforms' optimal price reactions with respect to prices  $p_1^{A,E}$ ,  $p_1^{B,E}$ ,  $p_2^{A,E}$  and  $p_2^{B,E}$  according to (13) to (14). They can be explicitly stated as

$$\begin{aligned} \frac{t^2}{T} n_1^{A,S} + \frac{1}{2T} (q^A + q^B) \left( -2q^B + p_2^{B,E} - p_2^{A,E} \right) - \frac{t}{2T} p_1^{A,E} - \frac{1}{2T} (q^A + q^B) p_2^{A,E} &= 0, \\ \frac{t^2}{T} n_1^{B,S} + \frac{1}{2T} (q^A + q^B) \left( -2q^A + p_2^{A,E} - p_2^{B,E} \right) - \frac{t}{2T} p_1^{B,E} - \frac{1}{2T} (q^A + q^B) p_2^{B,E} &= 0, \\ \frac{t^2}{T} n_2^{A,S} + \frac{1}{2T} (q^A + q^B) \left( -2q^B + p_1^{B,E} - p_1^{A,E} \right) - \frac{t}{2T} p_2^{A,E} - \frac{1}{2T} (q^A + q^B) p_1^{A,E} &= 0, \\ \frac{t^2}{T} n_2^{B,S} + \frac{1}{2T} (q^A + q^B) \left( -2q^A + p_1^{A,E} - p_1^{B,E} \right) - \frac{t}{2T} p_2^{B,E} - \frac{1}{2T} (q^A + q^B) p_1^{B,E} &= 0. \end{aligned}$$

Here we require  $t^2 > (q^B + q^A)^2$ , i.e.  $T > 0$ . This ensures concavity of profits in its prices and therefore unique equilibrium prices. Now, let us rewrite the system of equations in

form of a matrix:

$$\begin{aligned} & \begin{bmatrix} 2t & -t & 2(q^A + q^B) & -(q^A + q^B) \\ t & -2t & (q^A + q^B) & -2(q^A + q^B) \\ 2(q^A + q^B) & -(q^A + q^B) & 2t & -t \\ (q^A + q^B) & -2(q^A + q^B) & t & -2t \end{bmatrix} \begin{bmatrix} p_1^{A,E} \\ p_1^{B,E} \\ p_2^{A,E} \\ p_2^{B,E} \end{bmatrix} \\ &= \begin{bmatrix} t^2 + t(q^A - q^B) - 2q^B(q^A + q^B) \\ -t^2 + t(q^A - q^B) + 2q^A(q^A + q^B) \\ t^2 + t(q^A - q^B) - 2q^B(q^A + q^B) \\ -t^2 + t(q^A - q^B) + 2q^A(q^A + q^B) \end{bmatrix} \end{aligned}$$

By solving it we obtain equilibrium prices

$$\begin{aligned} p_i^{A,E} &= t - \frac{2}{3}(q^A + 2q^B) \\ p_i^{B,E} &= t - \frac{2}{3}(2q^A + q^B) \end{aligned}$$

as given in (15). From there, calculating price differences is straightforward and yields

$$p_i^{B,E} - p_i^{A,E} = \frac{2}{3}(q^B - q^A) \quad \text{and} \quad p_i^{A,E} - p_i^{B,E} = \frac{2}{3}(q^A - q^B).$$

By (11) and (12) this implies

$$\begin{aligned} n_i^{A,E} &= \frac{t^2}{T} \left[ \frac{1}{2} + \frac{q^A - q^B}{6t} \right] - \frac{1}{3T} (q^A + q^B) (2q^B + q^A), \\ n_i^{B,E} &= \frac{t^2}{T} \left[ \frac{1}{2} + \frac{q^B - q^A}{6t} \right] - \frac{1}{3T} (q^A + q^B) (2q^A + q^B) \end{aligned}$$

as in (16) and (17).

q.e.d

### Proof of Corollary 1:

Corollary 1 directly follows from (9) and (15).

**Proof of Lemma 3:**

Given standardisation of platforms, a platform  $a$ 's profit function is

$$\pi^a = \frac{1}{9t} (3t + q^a - q^b)^2 - \gamma (q^a)^2.$$

Let us maximise both platform  $A$ 's and platform  $B$ 's profit under the assumption of  $q^a \in [\underline{q}, \bar{q}]$  and  $0 < \underline{q} < \bar{q}$  as stated in Section 2. The first-order condition of a platform  $a$ 's profits with respect to its quality  $q^a$  given its rival's quality  $q^b$  is

$$\frac{\partial \pi^a}{\partial q^a} = \frac{2}{9t} (3t + q^a - q^b) - 2\gamma q^a = 0. \quad (22)$$

This will maximise the platform's profit iff

$$\frac{\partial^2 \pi^a}{(\partial q^a)^2} < 0$$

and holds for  $\gamma > 1/9t$ . Let us therefore distinguish between the cases  $\gamma \leq 1/9t$  and  $\gamma > 1/9t$ :

Re-considering (22) yields

$$\frac{2}{9t} (3t + q^a - q^b) - 2\gamma q^a > 0$$

if  $\gamma \leq 1/9t$  given  $q^a \in [\underline{q}, \bar{q}]$ . Hence,  $q^{a*} = \bar{q}$ , if  $\gamma \leq 1/9t$ .

For  $\gamma > 1/9t$ , let us simultaneously solve the first-order conditions for platform  $A$  and platform  $B$  according to (22), i.e.

$$\begin{aligned} \frac{2}{9t} (3t + q^A - q^B) - 2\gamma q^A &= 0 \quad \text{and} \\ \frac{2}{9t} (3t + q^B - q^A) - 2\gamma q^B &= 0. \end{aligned}$$

yields

$$q^{A*} = q^{B*} = \frac{1}{3\gamma}.$$

This represents an interior solution iff

$$\frac{1}{3\gamma} < \bar{q}.$$

Define

$$\bar{\gamma}^* \equiv \frac{1}{3\bar{q}}.$$

Then, equilibrium qualities are given by

$$q^{A^*} = q^{B^*} = \begin{cases} \bar{q} & \text{if } \gamma \leq \bar{\gamma}^* \\ \frac{1}{3\gamma} & \text{if } \gamma > \bar{\gamma}^* \end{cases}.$$

q.e.d

**Proof of Lemma 4:**

To obtain equilibrium qualities let us first have a look at the first derivative of an exclusive platform  $a$ 's profit, that are given in (19). The first derivative is

$$\begin{aligned} \frac{\partial \pi^a}{\partial q^a} &= \frac{4(q^A + q^B)}{T^2} \left[ t - \frac{2}{3}(q^a + 2q^b) \right] \left[ \frac{t^2}{2} + \frac{t(q^a - q^b)}{6} - \frac{1}{3}(q^a + q^b)(2q^b + q^a) \right] \\ &+ \frac{2}{T} \left[ -\frac{2}{3} \left( \frac{t^2}{2} + \frac{t(q^a - q^b)}{6} - \frac{1}{3}(q^a + q^b)(2q^b + q^a) \right) \right] \\ &+ \frac{2}{T} \left[ t - \frac{2}{3}(q^a + 2q^b) \right] \left[ \frac{t}{6} - \frac{2}{3}q^a - q^b \right] - 2\gamma q^a. \end{aligned}$$

This expression can be simplified to

$$\frac{\partial \pi^a}{\partial q^a} = -\frac{(3t - 2q^a - 4q^b)(t - 2q^a)}{9(t - (q^a + q^b))^2} - 2\gamma q^a.$$

Considering  $q^a, q^b \in [\underline{q}, \bar{q}]$  and  $\bar{q} < t/2$  according to Assumption 2, it becomes obvious that

$$\frac{\partial \pi^a}{\partial q^a} < 0.$$

Therefore, neither platform  $A$  nor platform  $B$  invest. In equilibrium,

$$q^{A,E^*} = q^{B,E^*} = \underline{q}.$$

q.e.d

**Proof of Proposition 3:**

The result directly follows from Lemma 3 and 4. By comparing equilibrium quality levels  $q^{a,S^*}$  and  $q^{a,E^*}$  it immediately follows that  $q^{a,S^*} > q^{a,E^*}$ .

q.e.d



**Proof of Lemma 5:**

For standardised platforms, joint profits amount to

$$\pi_c^S = \frac{1}{9t} (3t + q^A - q^B)^2 + \frac{1}{9t} (3t + q^B - q^A)^2 - \gamma(q^A)^2 - \gamma(q^B)^2 \quad (23)$$

$$= 2t + \frac{2}{9t} (q^A - q^B)^2 - \gamma(q^A)^2 - \gamma(q^B)^2. \quad (24)$$

Checking the Hessian, we cannot verify that the profit function is concave in its qualities  $q^A$  and  $q^B$  for all cost parameters  $\gamma$ . Therefore, instead of the regular first-order approach, let us examine the condition which ensures that an increasing quality  $q^a$  raises joint profits. Define

$$I = \pi_c^S(\cdot, q^a + \Delta, q^b) - \pi_c^S(\cdot, q^a, q^b).$$

Then, increasing quality  $q^a$  by  $\Delta$  is profitable if and only if  $I > 0$ . Inserting (24) and rearranging, this condition specifies to

$$\gamma < \frac{2}{9t} \left[ \frac{2(q^a - q^b) + \Delta}{2q^a + \Delta} \right] \leq \frac{2}{9t}. \quad (25)$$

Now differentiating  $I$  with respect to  $q^a$  and  $q^b$  yields

$$\frac{\partial I}{\partial q^a} > 0 \quad \text{if} \quad \gamma < \frac{2}{9t} \quad \text{and} \quad \frac{\partial I}{\partial q^b} < 0 \quad \forall \quad \gamma.$$

Therefore, platforms invest up to the limit in  $q^a$ , yet refrain from investing in  $q^b$  to maximise their profits subject to (25). Accordingly, joint profit maximisation leads to

$$\begin{aligned} q^a &= \underline{q} \quad ; \quad q^b = \bar{q} \quad \text{if} \quad \gamma < \bar{\gamma}_{AB}, \\ q^a &= q^b = \underline{q} \quad \text{if} \quad \gamma \geq \bar{\gamma}_{AB} \end{aligned}$$

where  $\bar{\gamma}_{AB} \equiv \frac{2}{9t}$  considering (25).

q.e.d

**Proof of Lemma 6:**

We consider joint profits  $\pi_c^{A,E} = \pi^{A,E} + \pi^{B,E}$ . The corresponding first-order condition with respect to a quality increase  $q^a$  is

$$\frac{\partial \pi_c^{a,E}}{\partial q^a} = -\frac{(3t - 2q^a - 4q^b)(t - 2q^a)}{9(t - (q^a + q^b))^2} - \frac{(3t - 4q^a - 2q^b)(5t - 4q^a - 6q^B)}{9(t - (q^a + q^b))^2} - 2\gamma q^a.$$

Similar to the proof of Lemma 4, we consider  $q^a \in [\underline{q}, \bar{q}]$  and  $\bar{q} < t/2$  according to Assumption 2. This reveals that

$$\frac{\partial \pi_c^{a,E}}{\partial q^a} < 0.$$

Therefore, there are no incentives to invest and equilibrium qualities are given by

$$q_c^{A,E} = q_c^{B,E} = \underline{q}.$$

q.e.d

#### Proof of Proposition 4:

Results follow immediately from Lemma 5 and Lemma 6.

#### Proof of Proposition 5:

Let us compare profits for the possible equilibrium constellations if  $\gamma < \bar{\gamma}_{AB}$ . The sum of profits when platforms standardise, but do not collude in qualities is

$$\sum_a \pi^{a,S} = 2t - 2\gamma\bar{q}^2. \quad (26)$$

If platforms standardise and choose qualities cooperatively, it is

$$\pi_c^S = 2t - \gamma\bar{q}^2 - \gamma\underline{q}^2 + \frac{2}{9t} (\bar{q} - \underline{q})^2. \quad (27)$$

In case of exclusivity, the possibility to collude does not affect aggregate profits, and therefore,

$$\sum_a \pi^{a,E} = 2t - 2\gamma\underline{q}^2 - 4\underline{q} = \pi_c^E. \quad (28)$$

Comparing (26) and (27), it becomes obvious that  $\pi_c^S > \sum_a \pi^{a,S}$ . Let us therefore rank profits with respect to profits under exclusivity. By (26) and (28) one has  $\sum_a \pi^{a,S} > \pi_c^E$  iff

$$2t - 2\gamma\bar{q}^2 > 2t - 2\gamma\underline{q}^2 - 4\underline{q}.$$

Rearranging yields

$$\begin{aligned} \sum_a \pi^{a,S} > \pi_c^E & \quad \text{if } \gamma < \bar{\gamma}_I \\ \pi_c^E \geq \sum_a \pi^{a,S} & \quad \text{if } \gamma \geq \bar{\gamma}_I \end{aligned}$$

where  $\gamma_I \equiv 2\underline{q}/(\bar{q}^2 - \underline{q}^2)$ . Similarly, using (27) and (28) we have  $\pi_c^S > \pi_c^E$  iff

$$\frac{2}{9t} (\bar{q} - \underline{q})^2 > \gamma (\bar{q}^2 - \underline{q}^2) - 4\underline{q}$$

which yields the condition

$$\gamma < \frac{2(\bar{q} - \underline{q})^2 + 36t\underline{q}}{9t(\bar{q}^2 - \underline{q}^2)} \equiv \tilde{\gamma}.$$

By a little rearranging  $\tilde{\gamma}$  becomes

$$\tilde{\gamma} = \frac{2(\bar{q}^2 + \underline{q}^2)}{9t(\bar{q}^2 - \underline{q}^2)} - \frac{2}{9t} \frac{2\bar{q}\underline{q}}{(\bar{q}^2 - \underline{q}^2)} + \frac{2}{9t} \frac{18t\underline{q}}{(\bar{q}^2 - \underline{q}^2)} > \frac{2}{9t} = \bar{\gamma}_{AB}.$$

It follows that  $\pi_c^S > \pi_c^E$  if  $\gamma < \bar{\gamma}_{AB}$ . In sum, the order of profits if  $\gamma < \bar{\gamma}_{AB}$  is

$$\begin{aligned} \pi_c^S &> \sum_a \pi^{a,S} > \pi_c^E = \sum_a \pi^{a,E} && \text{if } \gamma < \bar{\gamma}_I, \\ \pi_c^S &> \pi_c^E = \sum_a \pi^{a,E} > \sum_a \pi^{a,S} && \text{if } \bar{\gamma}_I \leq \gamma < \bar{\gamma}_{AB} \end{aligned}$$

q.e.d

### Proof of Proposition 6:

As for (i), let us consider profits of standardised platforms which collude if  $\bar{\gamma}_{AB} \leq \gamma < \bar{\gamma}^*$ .

It is

$$\pi_c^S = 2t - 2\gamma\underline{q}^2. \quad (29)$$

By comparing (29) to (26) and (28), using the results of Proof of Proposition 5, we conclude

$$\begin{aligned} \pi_c^S &\geq \sum_a \pi^{a,S} > \pi_c^E = \sum_a \pi^{a,E} && \text{if } \gamma < \bar{\gamma}_I, \\ \pi_c^S &> \pi_c^E = \sum_a \pi^{a,E} > \sum_a \pi^{a,S} && \text{if } \bar{\gamma}_I \leq \gamma < \bar{\gamma}^*. \end{aligned}$$

As for (ii) and (iii) we consider profits of standardised platforms competing in qualities if  $\gamma \geq \bar{\gamma}^*$ :

$$\sum_a \pi^{a,S} = 2t - \frac{2}{9\gamma}. \quad (30)$$

Considering (29) and  $\underline{q} \leq 1/3\gamma$  immediately implies  $\pi_c^S \geq \sum_a \pi^{a,S}$ . Further, by (28) and (29) one has  $\pi_c^S > \pi_c^E$  as before. Then, by (28) and (30) we have  $\sum_a \pi^{a,S} > \pi_c^E$  iff

$$2t - \frac{2}{9\gamma} > 2t - 2\gamma\underline{q}^2 - 4\underline{q}$$

which we can rewrite as

$$\frac{2\underline{q}}{\gamma} \left( \gamma^2 + \frac{2\gamma}{\underline{q}} - \frac{1}{9\underline{q}^2} \right) > 0.$$

Define

$$F(\gamma, \underline{q}, \bar{q}) \equiv \gamma^2 + \frac{2\gamma}{\underline{q}} - \frac{1}{9\underline{q}^2}$$

and solve this quadratic equation to obtain

$$F(\gamma, \underline{q}, \bar{q}) < 0 \quad \text{if} \quad \gamma < \bar{\gamma}_{II},$$

$$F(\gamma, \underline{q}, \bar{q}) \geq 0 \quad \text{if} \quad \gamma \geq \bar{\gamma}_{II}$$

where  $\bar{\gamma}_{II} \equiv (\sqrt{10} - 3) / (3\underline{q})$ . It then directly follows that

$$\pi_c^E > \sum_a \pi^{a,S} \quad \text{if} \quad \gamma < \bar{\gamma}_{II},$$

$$\pi_c^E \leq \sum_a \pi^{a,S} \quad \text{if} \quad \gamma \geq \bar{\gamma}_{II}.$$

Then, for all  $\gamma \geq \bar{\gamma}_{AB}$ , we obtain the following order of profits:

$$\pi_c^S \geq \sum_a \pi^{a,S} > \pi_c^E = \sum_a \pi^{a,E} \quad \text{if} \quad \gamma < \bar{\gamma}_I,$$

$$\pi_c^S > \pi_c^E = \sum_a \pi^{a,E} > \sum_a \pi^{a,S} \quad \text{if} \quad \bar{\gamma}_I \leq \gamma < \bar{\gamma}_{II}$$

$$\text{and} \quad \pi_c^S \geq \sum_a \pi^{a,S} > \pi_c^E = \sum_a \pi^{a,E} \quad \text{if} \quad \gamma \geq \bar{\gamma}_{II}.$$

Proposition 6 summarises these results.

q.e.d

**Proof of Proposition 7:**

In general, given that platforms agree on a common standard, welfare is

$$W^S = 2v_0 + 4q^A n_1^A n_2^A + 4q^B n_1^B n_2^B + 2(q^A + q^B) n_1^A n_2^B + 2(q^A + q^B) n_1^B n_2^A - t \left[ (n_1^A)^2 + (n_2^A)^2 + (n_1^B)^2 + (n_2^B)^2 \right] - \gamma \left[ (q^A)^2 + (q^B)^2 \right].$$

If platforms agree on exclusivity, it amounts to

$$W^E = 2v_0 + 4q^A n_1^A n_2^A + 4q^B n_1^B n_2^B - t \left[ (n_1^A)^2 + (n_2^A)^2 + (n_1^B)^2 + (n_2^B)^2 \right] - \gamma \left[ (q^A)^2 + (q^B)^2 \right].$$

1. Let us compare welfare for the possible equilibrium constellations if  $\gamma < \bar{\gamma}_{AB}$ . If  $\gamma < \bar{\gamma}_{AB}$ , then aggregate surplus in case of standardisation and quality competition amounts to

$$W^S = 2v_0 - t + 4\bar{q} - 2\gamma\bar{q}^2, \quad (31)$$

in case of standardisation and quality collusion it is

$$W_c^S = 2v_0 - t + 2(\underline{q} + \bar{q}) + \frac{5}{9t} (\bar{q} - \underline{q})^2 - \gamma (\bar{q}^2 + \underline{q}^2) \text{ and} \quad (32)$$

in case of exclusivity it is

$$W^E = W_c^E = 2v_0 - t + 2\underline{q} - 2\gamma\underline{q}^2. \quad (33)$$

In a first step, we look whether  $W_c^S > W^E$ . Due to (32) and (33), this requires

$$2\bar{q} + \frac{5}{9t} (\bar{q} - \underline{q})^2 - \gamma (\bar{q}^2 - \underline{q}^2) > 0.$$

By considering  $\gamma < \bar{\gamma}_{AB} < 1/(3\bar{q})$ , we obtain

$$2\bar{q} + \frac{5}{9t} (\bar{q} - \underline{q})^2 - \gamma (\bar{q}^2 - \underline{q}^2) > 2\bar{q} - \frac{1}{3} \left( \bar{q} - \frac{\underline{q}^2}{\bar{q}} \right) + \frac{5}{9t} (\bar{q} - \underline{q})^2 > 0$$

and conclude  $W_c^S > W^E$ .

In a second step, let us check whether  $W^S > W_c^S$ . Considering (31) and (32) this requires

$$2(\bar{q} - \underline{q}) - \frac{5}{9t} (\bar{q} - \underline{q})^2 - \gamma (\bar{q}^2 - \underline{q}^2) > 0.$$

Again, we look for a lower bound of the LHS to define a stricter condition. Considering  $\bar{\gamma}_{AB} < \frac{1}{3\bar{q}}$  and  $t > (\bar{q} - \underline{q})$  from Assumption 2, we can verify that

$$2(\bar{q} - \underline{q}) - \frac{5}{9}(\bar{q} - \underline{q}) - \frac{1}{3}\left(\bar{q} - \frac{q^2}{\bar{q}}\right) > 0,$$

and it follows that  $W^S > W_c^S$  if  $\gamma < \bar{\gamma}_{AB}$ . By transitivity, we conclude

$$W^S > W_c^S > W^E \quad \text{if} \quad \gamma < \bar{\gamma}_{AB}.$$

2. Let us now compare welfare for the possible equilibrium constellations if  $\bar{\gamma}_{AB} \leq \gamma < \bar{\gamma}^*$ . Here,  $W^S$  and  $W^E$  are given in (31) and (33), but

$$W_c^S = 2v_0 - t + 4\underline{q} - 2\gamma\underline{q}^2 \tag{34}$$

in case of standardisation and quality collusion. Comparing (31) and (34),  $W_c^S > W^E$  is obvious. Further,  $W^S > W_c^S$  requires

$$4\bar{q} - 2\gamma\bar{q}^2 > 4\underline{q} - 2\gamma\underline{q}^2,$$

and therefore

$$\gamma < \frac{2}{\bar{q} + \underline{q}}.$$

This condition is fulfilled, simply note that

$$\gamma < \frac{1}{3\bar{q}} < \frac{2}{\bar{q} + \bar{q}} < \frac{2}{\bar{q} + \underline{q}}.$$

Again it follows that

$$W^S > W_c^S > W^E \quad \text{if} \quad \bar{\gamma}_{AB} \leq \gamma \leq \bar{\gamma}^*$$

due to transitivity.

3. We now compare welfare for the possible equilibrium constellations if  $\gamma \geq \bar{\gamma}^*$ . Here,  $W_c^S$  and  $W^E$  are given in (33) and (34), but

$$W^S = 2v_0 - t + \frac{4}{3\gamma} - \frac{2}{9\gamma} \tag{35}$$

in case of standardisation and quality competition. From (34) and (35) it is obvious that  $W^S \geq W_c^S$  because  $\underline{q} \leq 1/(3\gamma)$ . Also  $W_c^S > W^E$  is obvious from (33) and (34). Due to transitivity, we conclude

$$W^S \geq W_c^S > W^E \quad \text{if} \quad \gamma \geq \bar{\gamma}^*.$$

In sum, for the entire defined range of  $\gamma$ ,

$$W^S \geq W_c^S > W^E.$$

q.e.d

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