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Platform Standards, Collusion and Quality Incentives

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Platform standards, collusion and quality incentives[†]

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Abstract

This paper examines how quality incentives are related to the interoperability of competing platforms. Platforms choose whether to operate standardised or exclusively, prior to quality and subsequent price competition. We find that platforms choose a common standard if they can coordinate their quality provision. The actual investment then depends on the cost of quality provision: If rather high, platforms refrain from investment; if rather low, platforms maintain vertically differentiated platforms. The latter case is socially more desirable than exclusivity where platforms do not invest. Nevertheless, quality competition of standardised platforms induces the highest investment and maximum welfare.

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1 Introduction

How are quality investments related to the interoperability of competing platforms ? By choosing whether to operate on a common standard, platforms decide on quality spillovers and to what extent network effects arise. This in turn influences competition and the profitability of investments. Platforms' decision about a common standard and investment incentives are therefore interdependent.

As an example for platform competition, consider the telecommunications industry. Here, some network providers claim that only exclusive rights will lead to quality investment. In fact, there is an ongoing debate, started by Schumpeter (1943) and Arrow (1962), whether standardisation or exclusivity, thus, spillovers or appropriability, stimulate innovation incentives. On a related note, the new regulatory framework 2002 of the EU (Directive 2002/19/EC) recommends but does not prescribe the use of standards to achieve interoperability.[1]

In our paper, we specifically relate to international phone calls over VoIP as an example for platform competition and, thus, a two-sided market: In a two-sided market, platforms serve as intermediaries between two distinct groups of users each of which values the number of users of the other group. Accordingly, VoIP providers serve to connect callers from one to another country where callers value the provider in proportion to their connectivity. Referring to this particular example, we study the effect of firms' interoperability choices on competition and subsequent quality investments. With respect to quality incentives, we consider the important role of standard-setting organisations and joint research in the telecommunications industry. Therefore, we incorporate the possibility of coordinated quality provision into our analysis.

By our analysis we link previous research on compatibility with the one on individual and joint research effort and apply it to competition in a two-sided market. Considerable discussion on compatibility has started with Farrell and Saloner (1985) and Katz and Shapiro (1985). These articles look at the coordination problem associated with an endogenous choice of compatibility and investigate the social optimal degree of it. We, in contrast, are mainly concerned with platforms' mutual agreement on a common standard,

[1] Common standards are published in the Directive 2002/19/EC on Access and Interconnection (related to network interconnection, this mainly refers to application interfaces and transmission protocols). Interoperability is also encouraged to achieve universal service.

i.e. two-way compatibility. Therefore, we simplify our analysis by considering the two polar cases of full two-way compatibility versus incompatibility only, namely, standardisation and exclusivity. This approach is similar to Economides (1986). But while Economides (1986) explores how standardisation affects competition in relation to product variety, we adhere to network externalities to investigate how firms' standardisation choice is linked to quality incentives. In this regard, we extend Armstrong (2006)'s and Armstrong and Wright (2006)'s example of platform competition. Like Doganoglu and Wright (2006), we consider two competing platforms which have to agree whether to standardise or not before they actually compete. But they study how multihoming agents, i.e. agents who subscribe to multiple platforms, affect platforms' choice to standardise. We, instead, examine quality incentives by adding a quality stage comparing individual with collusive efforts. In doing so, we follow D'Aspremont and Jaquemin (1988). Katz (1986), in this context, more thoroughly explores different types of cooperative R&D efforts where we distinguish between individual and joint research activity only. Note that our equilibrium results rely on the concept of "fulfilled expectations" with regard to platforms' market shares. This concept has been adopted by Katz and Shapiro (1985) and others before.

Our main insight relates to platforms' strategic incentive to choose a common standard in order to collude in qualities: Allowing platforms to coordinate their quality provision makes them choose a common standard. They do so because collusion prevents platforms to enter a quality race without any gains and because competition is more intense in case of exclusivity. When standardised platforms collaborate, they ensure the efficiency of their quality investment and abstain from unprofitably supplying the same high qualities. Indeed, they jointly maintain a high- and a low-performance platform in case quality provision is not too costly. Collusion in case of standardisation is, in effect, socially more desirable than exclusivity where platforms refrain from investment. Still, highest investments and maximum welfare are induced by quality competition of standardised platforms.

These results depend on the distinct character of platform competition and network effects. By their standardisation decision and by the possibility of collusive qualities platforms manipulate these market features. In fact, platforms choose a common standard to mitigate competition. The reason is that by standardisation, platforms allow their subscribers to connect to all opposite subscribers regardless of their platform choice. Therefore, platform specific feedback effects between user groups, that intensify competition, disappear. On a related note, collusion prevents platforms to enter a quality race which induces them to invest without any gains. Instead, they either jointly omit providing higher qualities or invest to establish asymmetric platforms. In the latter case, platforms gain from higher quality provision due to increasing network effects. Thus, their investment becomes profitable in and due to the presence of spillovers. These findings should, in principal, continue to hold if we considered additional connectivity within the same market side. This is so, as long as exclusivity in contrast to standardisation generates the above mentioned platform effects and as long as network effects exert positive externalities on subscribers' benefits.

That feedback effects between user groups intensify competition has already been observed by Armstrong (2006). Further, our results comply with Doganoglu and Wright (2006) in finding that standardisation serves to undermine this tendency. In addition to these insights, we relate the issue of platform competition and compatibility to quality incentives: Here, we obtain results opposite to D'Aspremont and Jaquemin (1988). In their model, investments decrease with larger spillovers whereas in our model, quality incentives arise with standardisation and therefore with large spillovers. In this context, cooperative quality investments further turn out to be socially more beneficial than exclusivity but they do not produce higher quality incentives and highest welfare as in D'Aspremont and Jaquemin (1988). The differences occur because we look at platform competition: Spillovers, strictly speaking, a common standard, here prevent feedback effects between user sides which - in case of exclusivity - give rise to more rigorous competition. Moreover, coordination, in our model, is crucial to firms as it enables them to vertically differentiate and exploit increasing network effects given a fixed market size. Such behaviour is omitted by assumption in D'Aspremont and Jaquemin (1988). Here, collusion gives higher incentives to invest with larger spillovers if it expands the market and significantly shifts demand upward.

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, total utility amounts to the benefit u_i^a of an agent i belonging to platform a reduced by the subscription fee and 'transport cost' tx_i, i.e.

$$U_i^a = u_i^a - p_i^a - tx_i \tag{1}$$

with t reflecting how much consumers' taste varies ex ante. A possible interpretation of cost induced by varying consumer taste include costs of learning about the new service and signing up for it. 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 neglect exclusionary strategies, therefore, we assume $q^a \in \left[\underline{q}, \overline{q}\right]$ where $0 < \underline{q} < \overline{q} < \frac{3}{4}t$. If, then, platforms decide to operate exclusively, benefits are equal to

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

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

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

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' 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 $C(q^a) = \gamma \left(q^a - \underline{q}\right)^2$. 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.[2] 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

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

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. $t^2 > (q^A + q^B)^2$

and

Assumption 3. $t \geq 1$.

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

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

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

[2] 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).

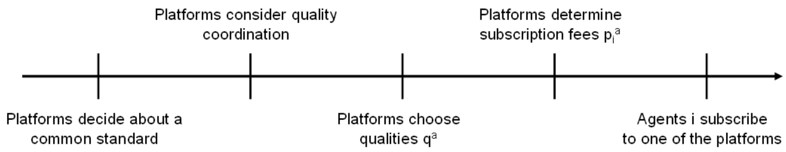

Figure 1: The Timing of the Game

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 $n_i^a = N_i^a$.[3]

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 marginal consumers x_i, indifferent between joining network A or B, for each market side $i = 1, 2$. This yields

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

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 between the case of standardisation and exclusivity:

[3] See Katz and Shapiro (1985).

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

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

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

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 interconnection and therefore, price competition in market 1 will not influence competition in market 2 or vice versa. Platforms' first-order conditions, correspondingly, are

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

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*

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

and market shares by

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

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 Δ_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

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

and

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

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:

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

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

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*

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

and market shares by

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

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

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

Thus, quality differences Δ_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* $i = 1, 2$.

Corollary 1 captures the key insight of our analysis: Platforms' standardisation decision changes the way platforms compete with each other. Clearly, qualities have a different effect on the market outcome. While quality changes affect a platform's competitivity in case of standardisation, they manipulate the strength of platform competition in case of exclusivity. From a platform's perspective, this immediately implies that standardisation can serve as a means to soften competition.

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.[4]

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

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

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

[4] 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. $\gamma \leq \overline{\gamma}^*$, where $\overline{\gamma}^* \equiv 1/3\overline{q}$, 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.[5]

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

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

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. [6]

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* $a = A, B$.

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[5] Given symmetry, profit maximisation becomes a question of cost minimisation leading to minimum quality levels.

[6] 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 π_c^S is not concave in qualities for all cost parameters γ 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

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

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 $q_c^{b,S^*} = \overline{q}$ if $\gamma < \overline{\gamma}_{AB}$. If, however, $\gamma \geq \overline{\gamma}_{AB}$, 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 $\gamma \geq \overline{\gamma}_{AB}$, 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 $\gamma < \overline{\gamma}_{AB}$ 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 $\overline{q}$ 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* $\gamma < \overline{\gamma}_{AB}$, *i.e.* $q_c^{A,S^*} + q_c^{B,S^*} > q_c^{A,E^*} + q_c^{B,E^*}$. *If, however,* $\gamma \geq \overline{\gamma}_{AB}$, *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 homogeneous consumers - if $\gamma < \overline{\gamma}_{AB}$ - exploiting network effects implies highest joint profits. Thus, quality investment takes place and asymmetric platforms arise.

5 Private and social incentives for interconnection

We now examine whether platforms prefer a common standard or exclusivity by comparing profits of potential market outcomes.[7] Indeed, incentive considerations of Lemma 5 and

[7] 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

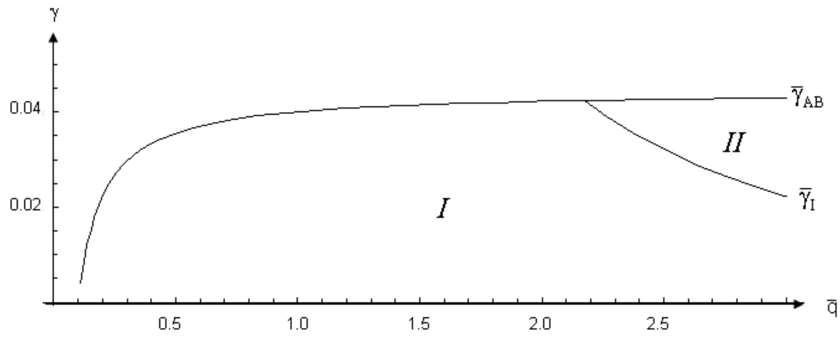

Figure 2: Profit outcomes, given $\underline{q} = 0.1$ and $t = 5$

uncoordinated quality provision. First, suppose a situation of relatively low quality cost where platforms vertically differentiate to maximise their profits:

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

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

(ii) If $\gamma \geq \overline{\gamma}_I$*, 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 γ and maximum quality $\overline{q}$, given baseline quality $\underline{q}$. The borderline between regions I and II is defined by $\overline{\gamma}_I\left(\underline{q}, \overline{q}\right)$.[8] 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

[8] For an explicit expression of $\overline{\gamma}_I\left(\underline{q}, \overline{q}\right)$ 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

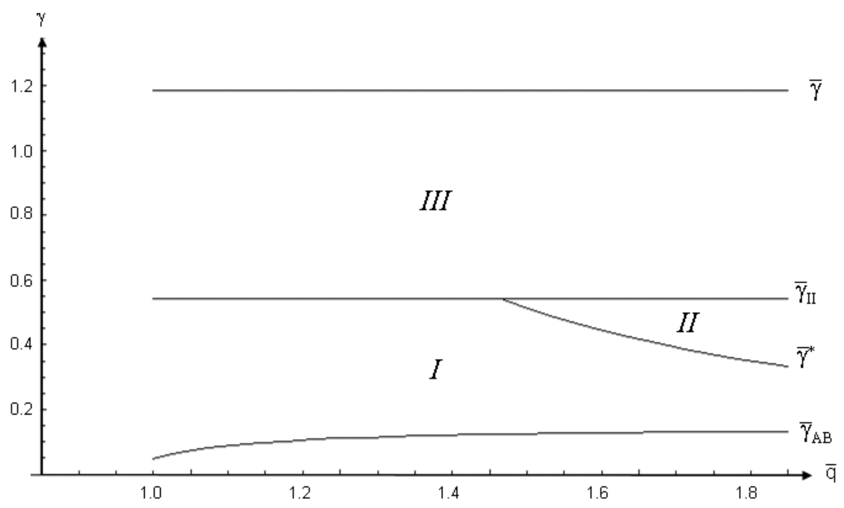

Figure 3: Profit outcomes, given $\underline{q} = 0.1$ and $t = 1.5$

in case a platform outperforms its rival. Coordination, in such a situation, prevents platforms 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 exists a $\overline{\gamma}_{II}\left(\underline{q}, \overline{q}\right)$ with $\overline{\gamma}_{AB} < \overline{\gamma}^{*} < \overline{\gamma}_{II} < 16/9t$ such that, with $a = A, B$, platforms' equilibrium profits under their different cooperative agreements can be ranked as follows:*

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

(ii) If $\overline{\gamma}^{*} \leq \gamma < \overline{\gamma}_{II}$, then $\pi_c^S > \pi_c^E = \sum_a \pi^{a,E} > \sum_a \pi^{a,S}$.

(iii) If $\gamma \geq \overline{\gamma}_{II}$, 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 γ and $\overline{q}$ 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: $W^S \geq W^S_c > W^E$, 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

In this paper, we regarded competition in a two-sided market and examined how platform interoperability affects platforms' quality incentives. We found that platforms refrain from quality investment in case of exclusivity, whereas they tend to invest in case of standardisation. Furthermore, we have shown that standardisation prevails in equilibrium, provided that platforms can coordinate their quality provision. Indeed, platforms coordinate to refrain from investment if cost of quality provision is rather high, and coordinate to create vertically differentiated platforms if the cost is rather low. Therefore, cooperative investment by standardised platforms might create higher aggregate surplus than exclusivity. But still, highest investment and surplus arise with standardisation and quality competition, as platforms enter a quality race then.

With regard to our example of VoIP communication services, we observe two standards were developed and adopted, namely, Skype by the International Telecommunication Union and H323.3 by the Internet Engineering Task Force. Whether our reasoning carries over to their co-existence and their different levels of diffusion remains an open question. Other arguments of competing standards pertain.

Since in our model quality incentives only arise with a common standard, our findings oppose political claims of granting exclusivity to produce investment incentives. They further indicate that costs and cooperative agreements play an important role when discussing investment incentives in a two-sided market. Indeed, they imply that it is unnecessary to mandate standardisation as long as research joint ventures are permitted. This suggests to encourage cooperative R&D efforts and, therefore, a permissive antitrust treatment of joint R&D initiatives. Yet, imposing a standard and prohibiting collusion - and therefore rigorous intervention - would achieve the welfare maximising outcome according to our model.

Within our 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 are realised, e.g. by technical means or by an adequate pricing structure. Likewise, assuming agents' full participation served to simplify our framework and sufficed to make our point. Including such extensions might alter underlying network effects and might therefore give rise to different 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 interconnected platforms can be described as

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

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

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

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

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

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

$$p_i^{A,S} = t_i + \frac{1}{3}\left(q^A - q^B\right),$$
$$p_i^{B,S} = t_i + \frac{1}{3}\left(q^B - q^A\right)$$

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

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

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

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

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

$$\pi^{A,E} = p_1^{A,E} n_1^{A,E} + p_2^{A,E} n_2^{A,E} - \gamma (q^A)^2 \quad \text{and} \tag{20}$$
$$\pi^{B,E} = p_1^{B,E} n_1^{B,E} + p_2^{B,E} n_2^{B,E} - \gamma (q^B)^2 \tag{21}$$

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

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

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:

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

$$= \begin{bmatrix} t^2 + t(q^A - q^B) - 2q^B(q^A+q^B) \\ -t^2 + t(q^A - q^B) + 2q^A(q^A+q^B) \\ t^2 + t(q^A - q^B) - 2q^B(q^A+q^B) \\ -t^2 + t(q^A - q^B) + 2q^A(q^A+q^B) \end{bmatrix}$$

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

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

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

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

The first derivative with respect to quality q^a can be expressed as

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

But before examining quality incentives in more detail, let us check whether a's profits are concave in qualities. To do so, we consider the Hessian

$$H(q^A, q^B) = \begin{bmatrix} \frac{2}{9t} - 2\gamma & -\frac{2}{9t} \\ -\frac{2}{9t} & \frac{2}{9t} - 2\gamma \end{bmatrix}$$

The profit function is concave if $H(q^A, q^B)$ is negative definite, i.e.

$$\left(\frac{2}{9t} - 2\gamma\right)^2 - \left(\frac{2}{9t}\right)^2 > 0.$$

Thus, platform a's profits are concave if $\gamma > 2/9t$.
Let us now look at (26) to examine quality incentives. There are incentives for higher q^a for any given q^b if

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

With simultaneous quality decisions this yields condition

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

Therefore, if $\gamma \leq \frac{1}{3\overline{q}}$ quality investment of a platform a is

$$q^{a^*} = \overline{q}.$$

By considering $0 < q^a < 3t/4$, the least upper bound of $\overline{\gamma}^*$ is given by $\sup(\overline{\gamma}^*) = 4/9t > 2/9t$. Therefore, we can derive both platforms' quality choice by the usual first-order conditions if $\gamma > \overline{\gamma}^*$. Considering (26), we, hence, simultaneously solve

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

This yields

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

We therefore summarise

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

q.e.d

Proof of Lemma 4:

We use platform a's profit in case of exclusivity as given in (19) to obtain the first derivative

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

This expression can be simplified to

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

By considering Assumption 2 and imposing symmetry, thus, $q^A = q^B$, we find that

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

Since this includes $q^A = q^B = \underline{q}$, there are no investment incentives in equilibrium, therefore,

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

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

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

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

By considering its Hessian, we find that this profit function is not concave in its qualities q^A and q^B for all cost parameters γ. Instead of using a first-order approach, we therefore look at unilateral incentives to invest. Using (28), we can specify the condition under which 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 Δ is profitable if and only if $I > 0$. By inserting (28) and rearranging, we get

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

Further differentiating I with respect to q^a and q^b yields

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

Therefore, platforms invest up to the limit in q^a, yet refrain from investing in q^b to maximise their profits subject to (29). Accordingly, joint profit maximisation leads to

$$q^a = \underline{q} \quad ; \quad q^b = \overline{q} \quad \text{if} \quad \gamma < \overline{\gamma}_{AB},$$

$$q^a = q^b = \underline{q} \quad \text{if} \quad \gamma \geq \overline{\gamma}_{AB}$$

where $\overline{\gamma}_{AB} \equiv \frac{2}{9t}\frac{\overline{q}-\underline{q}}{\overline{q}} < \frac{2}{9t}$.

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

$$\frac{\partial \pi_c^{a,E}}{\partial q^a} = -2 - 2\gamma q^a - \frac{(q^a - q^b)(q^a + 3q^b - 2t)}{T^2}.$$

By imposing symmetry with $q^A = q^B = q$, it simplifies to

$$-2(1 + \gamma q) < 0.$$

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

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 $\gamma < \overline{\gamma}_{AB}$. The sum of profits when platforms standardise, but do not collude in qualities is

$$\sum_a \pi^{a,S} = 2t - 2\gamma \overline{q}^2. \tag{26}$$

If platforms standardise and choose qualities cooperatively

$$\pi_c^S = 2t - \gamma \overline{q}^2 - \gamma \underline{q}^2 + \frac{2}{9t}\left(\overline{q} - \underline{q}\right)^2. \tag{27}$$

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

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

It is obvious from (30) and (31) that $\pi_c^S > \sum_a \pi^{a,S}$. Let us now classify the range of profits if platforms operate exclusively. By (30) and (32) one has $\sum_a \pi^{a,S} > \pi_c^E$ iff

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

Rearranging yields

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

$$\pi_c^E \geq \sum_a \pi^{a,S} \quad \text{if} \quad \gamma \geq \overline{\gamma}_I$$

where $\gamma_I \equiv 2\underline{q}/\left(\overline{q}^2 - \underline{q}^2\right)$. Similarly, using (31) and (32) we have $\pi_c^S > \pi_c^E$ iff

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

which yields the condition

$$\gamma < \frac{2\left(\overline{q} - \underline{q}\right)^2 + 36t\underline{q}}{9t\left(\overline{q}^2 - \underline{q}^2\right)} \equiv \widetilde{\gamma}.$$

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

$$\widetilde{\gamma} = \frac{2\left(\overline{q}^2 + \underline{q}^2\right)}{9t\left(\overline{q}^2 - \underline{q}^2\right)} - \frac{2}{9t}\frac{2\overline{q}\underline{q}}{\left(\overline{q}^2 - \underline{q}^2\right)} + \frac{2}{9t}\frac{18t\underline{q}}{\left(\overline{q}^2 - \underline{q}^2\right)} > \frac{2}{9t}.$$

Since $\overline{\gamma}_{AB} < 2/(9t)$, we conclude $\pi_c^S > \pi_c^E$ if $\gamma < \overline{\gamma}_{AB}$. In sum, the order of profits if $\gamma < \overline{\gamma}_{AB}$ is

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

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

q.e.d

Proof of Proposition 6:
As for (i), let us consider profits of standardised platforms which collude if $\overline{\gamma}_{AB} \leq \gamma < \overline{\gamma}^*$. It is

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

By comparing (33) to (30) and (32) we conclude

$$\pi_c^S > \sum_a \pi^{a,S} > \pi_c^E.$$

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

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

Considering (33) and $\underline{q} \leq 1/3\gamma$ immediately implies $\pi_c^S \geq \sum_a \pi^{a,S}$. Further, by (32) and (33) one has $\pi_c^S > \pi_c^E$ as before. Then, by (32) and (34) 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

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

and solve this quadratic equation to obtain

$$\begin{aligned} F\left(\gamma, \underline{q}, \overline{q}\right) &< 0 \quad \text{if} \quad \gamma < \overline{\gamma}_{II}, \\ F\left(\gamma, \underline{q}, \overline{q}\right) &\geq 0 \quad \text{if} \quad \gamma \geq \overline{\gamma}_{II} \end{aligned}$$

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

$$\begin{aligned} \pi_c^E &> \sum_a \pi^{a,S} \quad \text{if} \quad \gamma < \overline{\gamma}_{II}, \\ \pi_c^E &\leq \sum_a \pi^{a,S} \quad \text{if} \quad \gamma \geq \overline{\gamma}_{II}. \end{aligned}$$

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

$$\begin{aligned} &\pi_c^S \geq \sum_a \pi^{a,S} > \pi_c^E = \sum_a \pi^{a,E} \quad \text{if} \quad \gamma < \overline{\gamma}^*, \\ &\pi_c^S > \pi_c^E = \sum_a \pi^{a,E} > \sum_a \pi^{a,S} \quad \text{if} \quad \overline{\gamma}^* \leq \gamma < \overline{\gamma}_{II} \\ \text{and} \quad &\pi_c^S \geq \sum_a \pi^{a,S} > \pi_c^E = \sum_a \pi^{a,E} \quad \text{if} \quad \gamma \geq \overline{\gamma}_{II}. \end{aligned}$$

Proposition 6 summarises these results.

q.e.d

Proof of Proposition 7:

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

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

If platforms agree on exclusivity, it amounts to

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

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

$$W^S = 2v_0 - t + 4\overline{q} - 2\gamma\overline{q}^2, \tag{31}$$

in case of standardisation and quality collusion it is

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

in case of exclusivity it is

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

In a first step, we look whether $W_c^S > W^E$. Due to (36) and (37), this requires

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

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

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

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

In a second step, let us check whether $W^S > W_c^S$. Considering (35) and (36) this requires

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

Again, we look for a lower bound of the LHS to define and verify a stricter condition. Considering $\overline{\gamma}_{AB}<\frac{1}{3\overline{q}}$ and $t>\left(\overline{q}-\underline{q}\right)$ due to Assumption 2, we obtain such a condition. Since it is obvious that

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

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

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

2. Let us now compare welfare for the possible equilibrium constellations if $\overline{\gamma}_{AB}\le\gamma<\overline{\gamma}^*$. Here, W^S and W^E are given in (35) and (37), 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 (37) and (40), $W_c^S>W^E$ is obvious. Further, $W^S>W_c^S$ requires

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

and therefore

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

This condition is fulfilled, simply note that

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

Again it follows that

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

due to transitivity.

3. We now compare welfare for the possible equilibrium constellations if $\gamma\ge\overline{\gamma}^*$. Here,

W_c^S and W^E are given in (37) and (38), but

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

in case of standardisation and quality competition. From (38) and (39) 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 (37) and (38). Due to transitivity, we conclude

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

In sum, for the entire defined range of γ,

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

q.e.d

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