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Exclusive Content and the Next Generation Networks[*]

Juan José Ganuza[†] and María Fernanda Viecens[‡]

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Abstract

This paper analyzes the interaction between the market of premium contents and the next generation network industry. We assume structural separation between the network and service operators (platforms) and the comparative advantage of the service operators depends on the access to premium contents. On one side, we analyze the impact of the exclusivity of premium contents over the incentives to deploy NGNs, the performance of the operators market, and welfare. On the other side, we analyze what are the incentives of the providers of premium contents to offer exclusivity contracts (to singlehome) in NGNs settings in which they can also sell directly to consumers. In this context, we show that exclusivity only occurs when the content is not highly valued by consumers.

Keywords: Content exclusivity, next generation networks (NGNs), double marginalization.
JEL Classification: L1, L2, L8.

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1 Introduction

There is an upcoming revolution in the telecom industry. After 100 years of a stable technological framework based on copper networks, we are in front of a drastic innovation in the industry, to grant consumers with the advantages of the optical fiber. The deployment of fiber based Next Generation Networks (NGNs) will increase drastically the speed of broadband services (up to more than 100 MB).

The NGNs will multiply the demand and possibilities of existing Internet services and applications (P2P, Online Games, and so forth), and will allow for new services as HD Television on demand, and public applications to e-Education and e-Health. Besides, the structure of the telecom industry may change drastically. The shadow of the old incumbent national monopolies may disappear. The NGN is based on IP world and it does not require a centralized network. In fact, we are observing how many local public authorities or regional development agencies have decided to build their own infrastructure in order to boost the delivery of new services to their inhabitants.[1] Moreover, it is unclear who in the production chain (network operators, service operators and providers of contents) is going to get the largest share of the value created. Finally, from an economic policy point of view, the deployment of the NGNs may have an important impact over the whole economy: it may foster the digital content industry, it may increase productivity due to the efficiency gains in the production processes, it may improve public services (especially education and health), and so forth.

For all these reasons, the deployment of NGNs is at the center of the public debate on telecommunications and it is expected that the investment in NGNs will be huge in the next decade around the world.[2] However, nowadays the most important investment efforts have been done by (or with the help of) governments and public administrations.[3] Public investment has obvious limits due to the cost of public funding and for the fear of crowing out private initiatives. Then, it is key to analyze the incentive for private investment in NGN. From a telecom company point of view the

[1]See "Asturcom" in Asturias, Spain, "Xarxa Oberta Project" in Catalonia, Spain and "Pau Broadband Country" in France to mention a few of several cases. See also, Jullien et. al (2009) that consider investment in a next generation access network by local authorities. They focus on the interplay between the national regulator, an incumbent and the local authority.

[2]EC (Cecilio Madero, Director of Information, Communication and Media Directorate, DGComp, EC) estimates that the investment will be around of 250.000 millions of euros in EU.

[3]See for instances the NBN project in Australia and the Next Gen NBN in Singapore.

deployment of NGN is an expensive and risky investment.[4] It reduces drastically the values of its current assets and business model (ADSL, fixed telephony, etc..). The return is uncertain, the regulatory framework has not been established in most of the countries, it is long term investment and most of the applications that add value to it have not been developed yet, and as we said before, the potential profits must be shared with content providers and service operators. Most of these factors that preclude the investment are easy to understand (although difficult to affect). However, the interplay between all the agents of the production chain is not well understood yet. This paper tries to shed light over this vertical interaction, and gets insights over the potential effects that the access to premium content may have over the equilibrium outcome of the industry.

The premium contents determine the profitability (and the incentives to invest) of the network through two effects: a direct one and a strategic one. Firstly, the value of a network lies in the value of services to which it facilitates access. Consequently, the quality of contents that operators in the network provide plays a fundamental role in network success. Secondly, the viability of the investment will depend on the ability of the network to extract surplus from the service operators, and premium contents, which shape operators competition (since it is the main source of vertical differentiation), should be a determinant of the network profitability. This paper analyzes this second strategic effect.

We propose a model where an open network does not operate in the downstream market and gives access in a neutral way to two operators.[5] These two operators are competing platforms that, on one side, compete for consumers that singlehome (join one operator) and on the other side have access to contents. This accessibility determines competition on consumers' side. In particular, the platforms will be vertically differentiated as long as only one of them has access to the premium content. In the first part of the paper we take the exclusivity of the premium content as given, but we parametrize the scope of this exclusivity. We show that only the service operator who has access to the premium content obtains a positive demand. More interesting, the network profits and the consumer welfare are larger the lower is the comparative advantage of this service operator.

In the second part of the paper we introduce the content provider as a strategic player. Then,

[4]The average cost of reaching a consumer is between (600-1000 euros).

[5]Due to public ownership or existing regulation, many of the operating NGNs and most of the existing plans of NGNs follow this structural separation pattern.

he takes two decisions: whether or not to provide in exclusivity (by singlehoming) its premium content to an operator, and second whether or not, to keep the pricing control over its premium content (to sell directly to consumers). This second model is motivated by the fact that NGNs will allow content providers to reach consumers directly with its contents (via streaming, for example). Under this assumption we show, in contrast with the previous literature on the market of premium contents, that non exclusivity is the expected outcome when the premium content is highly valued by consumers. The complete characterization of the equilibrium involves exclusivity when the differentiation due to premium content is low. These results are driven by the complex pricing interaction between the network (access fee), operators (service price) and content provider (operator payments for exclusivity and content price).

The paper is organized as follows. In the rest of this section we offer a review of the related literature. In section 2 we present and solve the baseline model that takes exclusivity as given. In section 3, we introduce the strategic content provider within the model, and we analyze whether or not the exclusivity of the premium content arises in equilibrium. Section 4 contains a brief discussion of the implications, and concludes. All the proofs are exposed in the Appendix.

1.1 Related literature

Our article is related to the literature on next generation networks. Since it is an issue that has begun to arouse interest in recent years, there are only few specific papers on this. Brito et al. (2009) analyze the performance of two-part access tariffs in promoting investment in next generation networks. In particular, they focus on the interplay between access prices and infrastructure investment and study if two-part access tariffs solve the dynamic consistency problem of the regulation of NGN. [6] Another paper by the same authors, Brito et al. (2008), studies the incentives of an incumbent to invest and give access to a NGN. They assume that access to the old network is regulated, but access to the NGN is not. Nitsche and Wiethaus (2009) compare the effect on investment and consumer welfare of different regimes of access regulation

[6] The tension between promoting competition and promoting investment has been largely analyzed in the telecommunications economics literature (see Cambini and Jiang (2009) for a literature review). This literature is being retested today, in need of new deployments and the preoccupation of governments to prevent a resurgence of monopoly networks. Cave and Hatta (2009) identifies current government policy towards NGNs and de Bijl and Peitz (2008) discuss the challenges for telecommunications regulation from a European perspective.

to NGNs. Gotz (2009) examines the effect of regulation on both penetration and coverage of broadband access to the internet. In contrast to our paper, all of these papers model the industry as a duopoly, where a vertically integrated incumbent competes with a downstream entrant that requires access to the incumbent's network. The traditional copper and cable networks have followed a structure of vertical integration between network and customer services. Because of this, as far as we know, all existing models in telecommunications literature are set up in a market with vertically integrated firms, or with a vertically integrated incumbent and an entrant that asks for access to the incumbent's network. In contrast, our baseline model considers a firm that will operate a network but is not going to compete in the service market. This is a relevant analysis given that with new deployments of fiber, this industry structure is emerging around the world and we assist to the birth of many separated networks that give open access to service operators.

Besides, our focus is radically different because we concentrate on the role of content access by operators and consumers. Consequently, our paper is also related to the literature on exclusive contents (see Armstrong (1999) and Weeds (2009)). In particular, we assume that the provision of an exclusive premium content gives rise to a situation of vertical differentiation characterized by the fact that if two distinct operators offer services at the same price, then all consumers subscribe to the operator offering the content.[7] To the best of our knowledge the are two papers that model a vertical structure where retailers are vertically differentiated, Bolton and Bonanno (1988) and Spiegel and Yehezkel (2003). Bolton and Bonanno (1988) compare outcomes of a complete vertically integrated structure with a non integrated one. They analyze how optimal is the linear price contract and other kind of vertical restraints. In a similar setting, Spiegel and Yehezkel (2003) show that when markets cannot be vertically segmented and the cost difference between the retailers is not too large, the manufacturer will foreclose the low quality retailer. Related to this literature, Hagiu and Lee (2009) is the first paper to analyze the impact of the allocation of control rights over content pricing between content providers and platforms on whether content is exclusive to one platform or not. In a similar vein, but in a different setting, they show that non exclusivity may arise as an equilibrium outcome.

Papers in telecommunications assuming vertical differentiation, but also vertical integration,

[7] Stennek (2007) studies the incentives to invest of providers of contents in higher quality. Differently, we take as given the value of the contents.

are Kotakorpi (2006) and Foros (2003). Kotakorpi (2006) considers a model with a vertically integrated monopolist network provider who gives access to a fringe of rival operators in the retail sector. She examines the network operator's incentives for infrastructure investment and assumes that the final products of the incumbent and the fringe are vertically differentiated. There are also spillovers, given that the infrastructure investments have a positive effect on the rivals. Foros (2003) examines the interaction between a facility-based vertically integrated firm and an independent competitor in the retail market for broadband Internet connectivity. The vertically integrated firm undertakes an investment (broadband upgrades) that increases the quality of the input. Total welfare effect of access price regulation critically depends on which firm has the highest ability to transform input to output. The quality of the input component sold from the integrated firm is the same for both retailers, but the retailers may differ in their ability to offer value-added services.

Although they analyze a very different setting, our model is very close to the one proposed by Casadesus et.al.(2010). They study how competition between microprocessors affects the profits of a firm producing operating systems. The basic difference between our baseline model and theirs is the timing that we use. While they assume that the three firms set prices simultaneously, we assume that the network sets the access price first, and then operators set prices to consumers in a second stage, something that seems more appealing for our setting.

2 Model

There is a continuum of uniformly distributed consumers indexed by $\theta \sim U\,[0,1]$. They decide about subscribing to the service to one of two operators (platforms), A and B, that provide services and contents through a network. We assume that operator A has a more valuable set of premium contents in exclusivity so that a customer of type θ values the product of operator A at θ and values the product of operator B at $\lambda\theta$ where $0 < \lambda < 1$. Let p_A and p_B be the prices set by the operators, the indifferent consumer between subscribing to A and B, is given by

$$\theta^{AB} = \frac{p_A - p_B}{(1-\lambda)}$$

and the indifferent consumer between subscribing to B and not subscribing to any of them, is given by

$$\theta^{B0} = \frac{p_B}{\lambda}.$$

LEMMA 1 *Given p_A and p_B demand for operator A is given by $D_A = 1 - \theta^{AB}$ assuming the interval is positive; else, demand is zero. Demand for operator B is given by $D_B = \theta^{AB} - \theta^{B0}$ assuming $\theta^{AB} > \theta^{B0}$; else, demand is zero.*

To provide the service, operators need access to a network infrastructure that sets them an access fee per subscriber a. The network charges the fee in a non-discriminatory way. Consequently, profits of the operators are given by

$$\pi_i = (p_i - a) D_i \quad i: \ A, B.$$

We assume that marginal cost of the network is zero, but there exists a fixed cost F to deploy the infrastructure. We assume that F is distributed according to $F \sim G(F)$. Penetration (demand) for the network is the sum of the demands for both operators. Profits (gross of F) of the network are

$$\Pi = a (D_A + D_B)$$

and we assume that the probability of deployment is measured by $G(\Pi)$.

The timing of the game is the following: in the first stage the network decides about deployment and sets a. In a second stage operators compete in prices and consumers take subscription decisions. We solve the model by backward induction. Then, we start by characterizing the operators price equilibrium for a given price of the network's access fee.

2.1 Price services equilibrium

We look for the Nash equilibrium of the operators game taking a as given. We follow the same approach to Casadesus et al. (2010), and we consider that operator B is 'active' if the operator earns positive profits or is on the margin of earning positive profits. Being on the margin of earning profits arises when operator B is just pushed down to charging marginal cost (here a) and the lowest-value customer in the market is just indifferent between operators A and B. More formally, $p_B = a$ and $D_B = 0$, but $dD_B/dp_A > 0$, so that if operator A raises its price, operator B would have positive demand. In contrast, when operator B is not active, then at $p_B = a$ all customers in the market strictly prefer operator A to B and then the operator market is a monopoly. In what follows we will say that the operators market is a competitive regime if operator B has a positive demand and we will say that it is a limit pricing regime whenever operator B is on the margin of earning profits. Finally, we will consider that this market is a monopoly regime as long as operator B is not active.

We find that the level of a determines the regime that prevails in the operators market. As the following figure shows, if $a < \frac{\lambda}{2}$ there is a competitive regime, if $\frac{\lambda}{2} \leq a \leq \frac{\lambda}{2-\lambda}$ there is a limit pricing regime and if $a > \frac{\lambda}{2-\lambda}$ there is a monopoly regime.

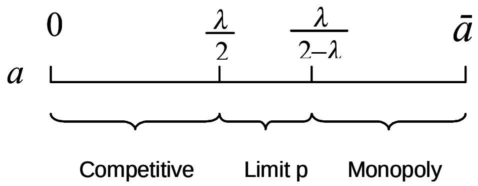

Figure 1

In the following Lemma we present the prices that operators set in equilibrium, for a given access fee a.

LEMMA 2 *Equilibrium prices are the following*

$$p_A(a) = \begin{cases} \frac{(3a+2(1-\lambda))}{4-\lambda} & a < \frac{\lambda}{2} \\ \frac{a}{\lambda} & \frac{\lambda}{2} \leq a \leq \frac{\lambda}{2-\lambda} \\ \frac{1}{2}(1+a) & a > \frac{\lambda}{2-\lambda} \end{cases},$$

$$p_B(a) = \begin{cases} \frac{(a(2+\lambda)+\lambda(1-\lambda))}{4-\lambda} & a < \frac{\lambda}{2} \\ a & \frac{\lambda}{2} \leq a \leq \frac{\lambda}{2-\lambda} \end{cases}.$$

The next figure illustrates the prices and the regimes (taken $\lambda = 0.7$).

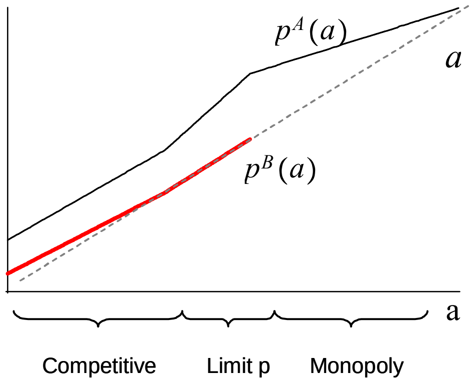

Figure 2

The access fee is the marginal cost of the firms. The equilibrium prices show us that an increase of the marginal cost leads to a larger comparative advantage of firm A. Taken λ as given, a low marginal cost allows for the presence of both operators. However, when the access fee is high, operator B is not able to compete in the market. The intuition behind that, is that when a increases, decreases the number of consumers with a willingness to pay larger than cost of providing the service. This demand reduction leads to a more homogenous set of consumers, limiting the possibilities of differentiation. Then, the environment becomes more competitive which are bad news for B because it has an inferior service.

It is obvious that the profits of firm B decreases in the access price. However, the fact that the larger a the larger the comparative advantage of firm A (and its market share) does not imply that the profits of firm A may increase in the access price. In particular, its profits given by

$$\pi_A(a) = \begin{cases} (1-\lambda)\frac{(2-a)^2}{(4-\lambda)^2} & a < \frac{\lambda}{2} \\ a(1-\lambda)\frac{\lambda-a}{\lambda^2} & \frac{\lambda}{2} \leq a \leq \frac{\lambda}{2-\lambda} \\ \frac{1}{4}(1-a)^2 & a > \frac{\lambda}{2-\lambda} \end{cases}$$

are continuous and decreasing in a.

It is also evident that the prevalence of each regime is conditioned by λ. The next figure depicts the operators A's profits and shows how the ranges under which each regime prevails move when λ changes. Solid line shows us the profits of firm A when $\lambda = 0.45$ and dashed line does when

$\lambda = 0.7$.

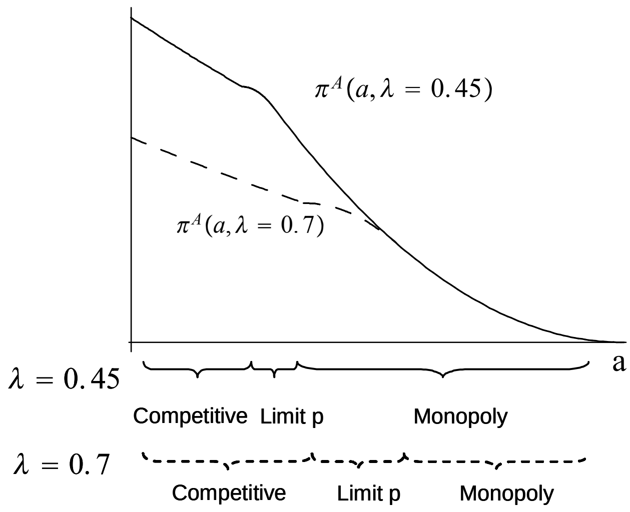

Figure 3

It is easy to see that both cut-off points, $\frac{\lambda}{2}$ and $\frac{\lambda}{2-\lambda}$, are increasing in λ. Moreover, the range under which a limit pricing regime occurs becomes wider as λ increases. If λ is high, such that $a < \frac{\lambda}{2}$ is profitable for operator A to accept the presence of operator B, instead of pushing it out by lowering p_A. Consequently, the higher λ, the higher the probability of operator B of having a positive demand. As expected, a higher λ reduces also the probability of a monopoly regime to arise. If differentiation is low, it will be hard for operator A to charge the monopoly price without inducing entry by operator B.

2.2 The network problem (SPNE)

In the first stage the network decides about investment and optimally chooses the access fee to be charged to the operators. From previous analysis we deduce that the level of competition in the retail market is decreasing in a as a higher a stresses condition $\lambda > 2a$ and relaxes condition $\frac{2a}{1+a}$. Moreover, setting a creates a double marginalization problem which may be alleviated by impulsing competition between operators. Consequently, the network faces a trade-off: it may set a low fee to induce competition and large penetration or a high fee that will lead to a monopoly market. The following results show us that the network sets a fee such that demand of operator B is zero for any λ. However the operator B plays a role in equilibrium. If λ is high enough, the network will leave operator B active and taking advantage over its competitive pressure. The next Lemma states the equilibrium access fee.

Lemma 3 *The network sets the following access fee*

$$a = \begin{cases} \frac{1}{2} & \lambda < \frac{1}{2} \\ \frac{1}{2}\lambda & \lambda \geq \frac{1}{2} \end{cases} . \tag{1}$$

If vertical differentiation between operators driven by contents is rather low (i.e.; $\lambda > \frac{1}{2}$), it is profitable for the network to boost penetration and to encourage competition (at least in the margin) by setting a low fee $\frac{1}{2}\lambda$. When operator B is active on the margin, it exerts a competitive pressure so that the operator A's margin ($p_A - a = \frac{1}{2}(1-\lambda)$) is lower than the margin when the comparative advantage of operator A due to contents is larger and operator B is not active ($p_A - a = \frac{1}{4}$). This results show us that the double marginalization is decreasing in λ.

Now we present the main result of this section that follows from observing the gross profits of the network which are given by

$$\Pi = \begin{cases} \frac{1}{8} & \lambda < \frac{1}{2} \\ \frac{1}{4}\lambda & \lambda \geq \frac{1}{2} \end{cases} . \tag{2}$$

Proposition 1 *The probability of deployment (network profit net of investment) is weakly increasing in λ.*

This Proposition shows that there is a strong relationship between the incentives to deploy the network and the structure of the market of contents. By simple computation it can also be shown that penetration, consumer surplus and total welfare are higher when operator B is active on the margin.

Proposition 2 *Penetration, consumer surplus and total welfare are weakly increasing in λ.*

Last results stem from two effects: on the one hand an increase in λ mitigates double marginalization, as explained above. On the other hand, a higher λ implies that consumers have access to a larger subset of premium contents. Then, a larger λ implies that operator B may offer a better product.

Note that, for a given λ, regulation of a would decrease the probability of investment (as a is not optimal, network profits have to be lower) but would induce lower prices in the retail market. As already known, regulation of a may impose a conflict between investment and competition.[8]

[8]See Cambini and Jiang (2009) for a literature review on this issue.

In contrast, avoiding excessive concentration in the market of contents helps to solve the two problems simultaneously: it increases the probability of deploying the network and induces lower prices in the retail market.

Regarding the operators surplus, we know from Lemma 2 and Lemma 3 that, independently of λ, operator B will have not a positive demand. The next Proposition shows us the equilibrium profits of the operator A.

PROPOSITION 3 *In equilibrium profits of the operator A are given by*

$$\pi_A = \begin{cases} \frac{1}{16} & \lambda < \frac{1}{2} \\ \frac{1}{4}(1-\lambda) & \lambda \geq \frac{1}{2} \end{cases} . \tag{3}$$

Notice that operator A does better if $\lambda \in \left[\frac{1}{2}, \frac{3}{4}\right]$ than when $\lambda < \frac{1}{2}$. Thus reducing the market concentration of contents may be profitable even for the operator that owns the exclusivity. This is because, when $\lambda < \frac{1}{2}$ the network sets a very high access fee which hurts operator's profits, while a more balanced contents market leads to the network to a penetration strategy profitable for operators.

3 Strategic content provider

In the baseline model we have implicitly assumed that operator A either owns the premium contents or has paid a fixed price for them. In this section, we extend the previous model by considering that the difference in the sets of premium contents between operators A and B is controlled by a content provider. In particular, operators can offer a basic service which is valued by consumer θ at $\lambda\theta$ and the content provider holds a premium content which is valued at $(1-\lambda)\theta$ by consumer θ. Notice that this model is equivalent to the previous one, in which one operator controls the premium content and a consumer θ values the bundle of basic service plus premium content at $\lambda\theta + (1-\lambda)\theta = \theta$.

NGNs open the possibility to content providers to sell directly to consumers the premium contents. For example, using streaming, blockbuster movies can be offered to the network consumers at the same time than official opening.[9] We will analyze what are the consequences of this

[9] In fact, some premium rights owners are already responding with new strategies including the launch of their own web TV services, as NFL, NBA (see Analysis Mason (2010)).

possibility. We will assume that the provider can sell the content directly to consumers and we will see under what conditions the provider wants to engage in an exclusive contract with some operator.

The rest of the model is identical to the baseline model but there exists a stage, previous to the stated ones, where the owner of the premium content makes a take it or leave it offer to one operator, the operator A by default, or to both operators. This offer specifies a fixed fee paid by the operator for providing the premium content and the price c that subscribers have to paid for it. We are assuming that the content provider has all the bargaining power, and then he sets the fixed fee equal to $\pi_A - \pi_B$ which allows him to extract the additional surplus that the content confers to operator A.[10] Notice that with non exclusivity the fixed fee is equal to zero and the content provider obtains all the revenues through c.

The timing is as follows: first, the content provider decides about exclusivity and accordingly sets c and the fixed payment. Then, the network chooses the access fee a, and finally operators compete in prices. We solve the model by backward induction.

We start analyzing the market outcome as long as there is no content exclusivity. Then, we determine the equilibria under exclusivity with operator A. Finally, we compare both solutions and we characterize the optimal strategy regarding exclusivity of the content provider.

3.1 The market outcome under non exclusivity

Assume that the provider decides to offer its contents in an "open" and non exclusive way to consumers. They will need access to some platform if they want to buy the premium content, but they are indifferent about which of them, i.e., the Hollywood creators design a web page and sells directly to consumers that have access to Internet.

In this setting the operators are not differentiated and both offer the same "basic" service, Bertrand competition takes place in the operators market, and then $p_A^{NE} = p_B^{NE} = a^{NE}$. Consumers may subscribe to the basic service and some of them may also buy the content. It determines a demand for the content provider, the premium demand D_{cp}^{NE}, a demand for the basic service D_{basic}^{NE} and the penetration of the network given by $D_{penetration}^{NE} = D_{cp}^{NE} + D_{basic}^{NE}$.

[10] We think that this is a sensible assumption since content providers are selling to pre-existing networks in different markets and they can commit to international pricing policies.

Consumers of the premium content are those such that $\theta \geq a^{NE} + c^{NE}$, whereas consumers in the interval $\frac{a^{NE}}{\lambda} < \theta < a^{NE} + c^{NE}$ will only subscribe to the basic service. As $c^{NE}\frac{\lambda}{1-\lambda} < a^{NE}$ holds (the price of the content is sufficiently low and quality sufficiently high compared to the network fee), last set of consumers disappears and then all the consumers that subscribe to the basic service also buy the premium content. Therefore,

$$D^{NE}_{penetration} = \begin{cases} 1 - \frac{a^{NE}}{\lambda} & a^{NE} < c^{NE}\frac{\lambda}{1-\lambda} \\ 1 - \left(a^{NE} + c^{NE}\right) & a^{NE} > c^{NE}\frac{\lambda}{1-\lambda} \end{cases}.$$

If a is low, penetration will be high and then consumers with lower θ will not buy the premium content. In contrast, as long as a is high, penetration will be rather low and all the subscribers will also buy the content.

Lemma 4 *With no exclusivity the strategy of the network is the following*

$$a^{NE} = \begin{cases} \frac{1}{2}\left(1 - c^{NE}\right) & c^{NE} < 1 - \sqrt{\lambda} \\ \frac{1}{2}\lambda & c^{NE} > 1 - \sqrt{\lambda} \end{cases}.$$

The network fee is non increasing in c, as the following figure shows.

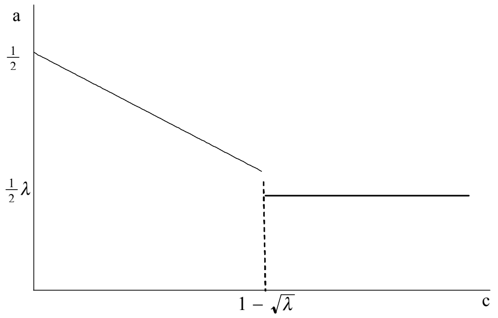

Figure 4

Notice that a and c are strategic substitutes, something what might expect, given that the network and the content are complements. If c is rather low (we are in the first case), the network sets a high fee which is strictly decreasing in c ($c < 1 - \sqrt{\lambda} \Rightarrow \frac{1}{2}(1-c) > \frac{1}{2}\lambda$). In such case, all subscribers buy the content and then c affects the marginal consumer of the basic service and consequently the network penetration and fee. In contrast, if c is high, subscribers in the margin of penetration are only affected by a (since they do not buy the content). Thus, in this case, the optimal network fee should not depend locally on c.

Given the network reaction function, the content provider will set its fee depending on the value of λ. The provider will set a c such that all subscribers buy the content or will set a high c that leads some subscribers to only consume the basic service.

Lemma 5 *With no exclusivity the strategy of the content provider is the following*

$$c^{NE} = \begin{cases} \frac{1}{2} & \lambda < \hat{\lambda} \\ 1 - \sqrt{\lambda} & \lambda > \hat{\lambda} \end{cases},$$

and it yields profits

$$\pi_{cp}^{NE} = \begin{cases} \frac{1}{8} & \lambda < \hat{\lambda} \\ \left(1 - \sqrt{\lambda}\right)\left(1 - \frac{(1-\sqrt{\lambda})}{(1-\lambda)}\right) & \lambda > \hat{\lambda} \end{cases},$$

where $\hat{\lambda}$ *is implicitly defined by* $\left(1 - \sqrt{\hat{\lambda}}\right)\left(1 - \frac{\left(1-\sqrt{\hat{\lambda}}\right)}{(1-\hat{\lambda})}\right) = \frac{1}{8} \Rightarrow \widehat{\lambda} \simeq 0.03.$

As $\lambda < \hat{\lambda}$ the content is of a very high quality, and then all the subscribers buy the content. In contrast, as $\lambda > \hat{\lambda}$ there will be a group of subscribers that will not pay for the content. Notice that the price is not monotonic in the quality of the premium content. The price when $\lambda < \hat{\lambda}$ is lower than when $\lambda \in [\hat{\lambda}, \frac{1}{4}]$. This is because in the first case the content provider internalizes the effect of his price over penetration, while in the second case, the content provider sets a very high price which forces the network to focus on the basic service market, setting a low fee and obtaining the profits through a wider penetration.

3.2 Equilibria with exclusivity

Previous sections considered two situations: one the one hand, the baseline model is equivalent to assume that the provider charges $c = 0$ and a fixed payment to operator A for the content exclusivity. On the other hand we have assumed that the provider charges directly to consumers the variable price c for the content with no exclusivity.

The interest of this section is to determine if there is any equilibrium under which the content provider sets $c \geq 0$ and prefers exclusivity (by a fixed payment) with operator A.[11]

We make an overview of the equilibrium analysis of subgame (the second and the third stages of the game) and we refer interested readers in the detailed analysis to the technical Appendix. Under exclusivity with operator A, the outcome of the pricing game is very similar to pricing

[11] We are assuming that the price of the premium content must be weakly positive. We disregard negative prices, and this is an assumption, since as we will see below, theoretically there may be equilibria with high fixed payments and negative prices. We do not think that negative prices are realistic, for example, for competition policy considerations.

equilibrium described in Figure 1 and Lemma 2: given λ and c, the network access fee a determines the structure of the market in the following way.

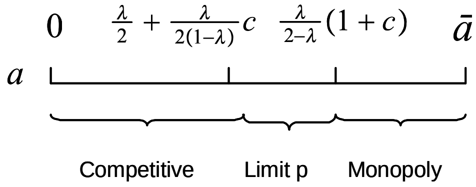

Figure 5

We want just to highlight that c reduces the comparative advantage of operator A and consequently expands the competitive regime to a larger set of parameters.

Regarding the network decision, taking as given the price of the premium content and λ, it deals with the same trade-off between penetration and high margin of the baseline model. The following Lemma characterizes the network strategies:

LEMMA 6 *There are functions,* $c_1(\lambda)$ *and* $c_2(\lambda)$*, and* $c_3(\lambda)$ *decreasing in* λ*, and there exists* $\bar{\lambda}$ *where* $c_1(\bar{\lambda}) = c_2(\bar{\lambda}) = c_3(\bar{\lambda})$ *such that:*

i) take $\lambda > \bar{\lambda}$*: if* $c > c_1(\lambda)$ *the network induces a competitive regime, if* $c_2(\lambda) < c < c_1(\lambda)$ *the network induces a limit pricing regime and if* $c < c_2(\lambda)$ *the network induces a monopoly regime.*

ii) take $\lambda < \bar{\lambda}$*: if* $c > c_3(\lambda)$ *the network induces a competitive regime and if* $c < c_3(\lambda)$ *the network induces a monopoly regime.*

We provide the proof of the Lemma in the Appendix. However, its intuition is clear if we observe the next picture. There we find, for each pair of (λ, c), the strategy that the network will follow.

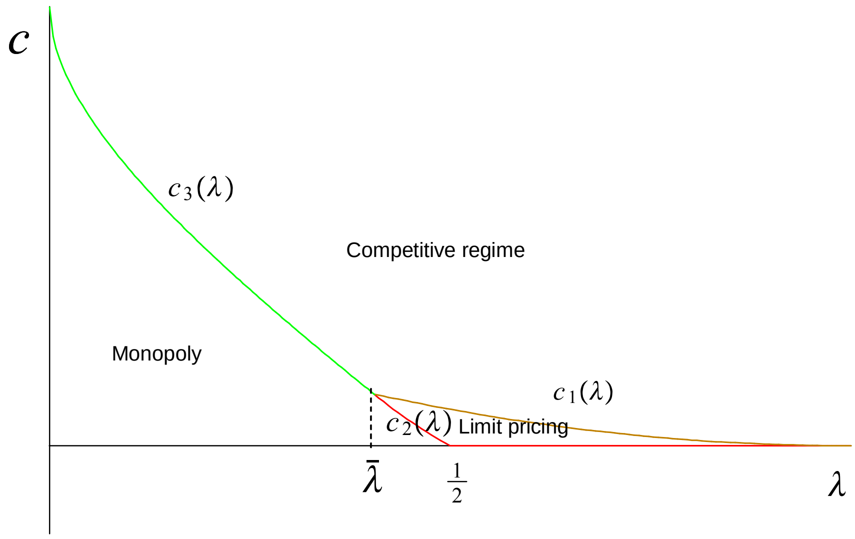

Figure 6

In particular, $c_1(\lambda)$ shows pairs (λ, c) under which the network is indifferent between profits in the competitive regime and profits in the limit pricing regime. Larger (lower) c makes the competitive (limit pricing) regime more attractive. Similarly, $c_2(\lambda)$ shows pairs (λ, c) under which the network is indifferent between profits in the limit pricing and the monopoly. Larger (lower) c makes the limit pricing (monopoly) regime more attractive. Finally, $c_3(\lambda)$ shows pairs of (λ, c) under which the network is indifferent between profits in the competitive regime and profits in the monopoly regime. Larger (lower) c makes the competitive (monopoly) regime more attractive. Then, these functions define binary orders among the regimes, in the Appendix it is shown how using transitivity we can characterize the optimal regime for every pair (λ, c).

Finally, we focus on the decision of the content provider that determines the subgame perfect Nash equilibrium.

Lemma 7 *There exists* $\lambda_2 \epsilon \left(\frac{1}{2}, 1\right)$ *such that, as* $\lambda < \bar{\lambda}$, *the content provider chooses a competitive regime by setting* $c_3(\lambda)$. *As* $\lambda \epsilon \left(\bar{\lambda}, \lambda_2\right)$ *the provider sets* $c_2(\lambda)$ *and induces a limit pricing regime and as* $\lambda \epsilon (\lambda_2, 1)$ *the provider sets* $\bar{c}(\lambda) > c_1(\lambda)$ *and induces a competitive regime.*

We want to notice that in general $(\lambda \notin \left(\frac{1}{2}, \lambda_2\right))$ it is not optimal for the content provider to set $c = 0$ and to take all the revenues through the fixed payment. There is a range $(\lambda \in \left(\frac{1}{2}, \lambda_2\right))$ in which the optimal c is equal to 0 and this does not depend on our assumption of positive prices. Although we have considered that $c_2(\lambda)$ is constrained to be higher or equal than 0, $c = 0$ is also the best response of the content provider for all possible prices (including negative ones) in the range. In other words, our constraint was not binding in the optimal response as $\lambda \in \left(\frac{1}{2}, \lambda_2\right)$.

3.3 Exclusivity versus non exclusivity

We have characterized the optimal strategy of the content provider in case of exclusivity and non exclusivity. Next Proposition compares both and establishes the condition under which exclusivity is an equilibrium.

PROPOSITION 4 *There exists* $\lambda^* \epsilon \left(0, \bar{\lambda}\right)$ *such that, as* $\lambda < \lambda^*$ *there is no exclusivity, and as* $\lambda > \lambda^*$ *the provider signs an exclusive contract with operator A.*

Non exclusivity allows the content provider to extract better the consumer surplus but it generates a double marginalization problem with the network. Under exclusivity, if $c > 0$, there is an additional marginalization as operators do not set their marginal cost prices. However counterintuitive, this "triple marginalization" may be more profitable than double marginalization for the content provider. The cost of exclusivity is that it makes harder to extract consumer surplus. Then, when the premium content is highly valued by consumers ($\lambda < \lambda^*$) non exclusivity dominates, while that when the willingness to pay of consumers for the premium content is low ($\lambda > \lambda^*$), exclusivity is the equilibrium outcome.

4 Discussion and concluding remarks

This paper analyzes the interaction between the market of premium contents and the next generation network industry. On one side, we have analyzed the impact of the exclusivity of premium contents over the incentives to deploy NGNs, the performance of the market of telecom operators, and welfare. On the other side, we have analyzed what are the incentives of the providers of premium contents to offer exclusivity contracts in NGNs settings. In particular, we have contributed in several ways to the new literature on NGNs.

As far as we know, this is the first paper in analyzing a NGNs setting under structural separation between the network and telecom service operators. Even though there is regulatory uncertainty over NGNs since most of the countries have not established yet clear market rules, we consider that structural separation is likely to be the leading regulatory framework. This is because most of the NGN initiatives have been partially or completely financed by public funds. Moreover, NGNs are a natural monopoly for the consumer (it is very unlikely that consumers may access to several networks) then as the services of the NGN become more important for consumer's welfare (affect for example to education or health services) the network access regulation should become more strict.

In the baseline model, consistently with the literature of the market of premiums contents, we take exclusivity as given and analyze how the scope of such exclusivity affect the profitability of the network (and the incentives to deploy it) as well as consumer surplus. Our main message is that the lower the vertical differentiation of the service operator market due to premium content, the larger the network profits, the incentives to invest and welfare.[12] Moreover, given the pricing game between the network and the operators, the profits of the operator holding the exclusivity of the premium content is not monotonic with respect to his comparative advantage in contents.

In the second part of the paper we introduce in the model a new player, the strategic content provider, and we endogenize the exclusivity of the premium contents. The strategy of a content provider is driven by the fact that the NGN technology allows him to sell the content directly to consumers. The assumption that the content provider will be able to charge consumers directly (thanks to NGNs) changes completely the standard results regarding exclusivity. In the previous literature (see for example Armstrong (1999)) the content provider does not have access to consumers and then the best strategy is to make an auction among operators. Given that the willingness to pay of a monopolist is larger than the aggregate willingness to pay of an oligopoly, the auction leads to exclusivity. In our framework, when the content provider does not sign any exclusivity contract and he may charge a fee to consumers for the content, he is keeping the monopoly power. In fact, we show that non exclusivity is the expected outcome when the premium content is highly valued by consumers.[13] Consequently, the deployment of NGNs and the

[12] An important underlying assumption is the one related to the timing of the game. We think that it is natural to assume that the network operator sets prices before the service operators get in to the game. However, it is likely that service operators were active in other markets and, as content providers, they may have some capability to have general pricing policies. Consequently, it is important to check the robustness of our main result with respect to the timing. In particular, to consider a setting where the network operator sets prices simultaneously with service operators. Motivated by the complementarity between operating systems and microprocessors, Casadesus et. al, (2010) have solved this game and they reach to a similar conclusion to the our.

[13] This result is similar to the one obtained by Hagiu and Lee (2009). This paper analyzes a model of content provides and content distributors, and it shows that propensity for exclusivity can be increasing, decreasing or

wider access to these networks by population will imply that very good contents will not be sold in exclusivity, reducing current concerns about exclusivity of premium contents.

There is another important implication of our analysis for the industry. As we have pointed out in the introduction, NGNs imply a revolution for the industry, and, as in every revolution there will be winners and losers. From our exposition it is deduced that content providers are clear winners. However, in our open neutral network setting, there are not obvious sources of profits for traditional telecom service operators, unless they find the way to offer a differentiated service. In other words, NGNs are challenging the traditional business model of telecoms.

even non monotonic in content quality. In our model with three layers in which exclusivity is determined by the interaction between access fee to the network, operators service prices and the price of the premium content, we obtain a decreasing relationship between exclusivity and the quality of the premium content.

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Appendix

Proof of Lemma 2: When operator B is active, reaction functions are the following

$$\begin{aligned} p_A(p_B) &= \frac{1}{2}\left(a + p_B + (1-\lambda)\right), \\ p_B(p_A) &= \frac{1}{2}\left(a + p_A\lambda\right). \end{aligned} \tag{4}$$

Simultaneously solving reaction functions yields prices $p_A(a) = \frac{(3a+2(1-\lambda))}{4-\lambda}$ and $p_B(a) = \frac{(a(2+\lambda)+\lambda(1-\lambda))}{4-\lambda}$ such that the corresponding levels of penetration are given by $D_A(a) = \frac{(2-a)}{(4-\lambda)}$ and $D_B(a) = \frac{(\lambda-2a)}{\lambda(4-\lambda)}$. It follows that this is an equilibrium, where $D_B > 0$ and operators compete, as long as $a < \frac{\lambda}{2}$.

If $a > \frac{\lambda}{2}$ operator A will be alone in the service market, however setting the monopoly price $p_A(a) = \frac{1}{2}(1+a)$ will be an equilibrium if $a > \frac{\lambda}{2-\lambda}$, otherwise operator B would have room of making positive profits and would enter to the market. For the range $\frac{\lambda}{2} \leq a \leq \frac{\lambda}{2-\lambda}$ operator A will set a limit price $p_A(a) = \frac{a}{\lambda}$ such that operator B will decide stay out of the market, although active on the margin, by setting $p_B = a$. ■.

Proof of Lemma 3: The network has to choose a to maximize

$$\Pi(a) = \begin{cases} a\left(\frac{(3\lambda - a(\lambda+2))}{\lambda(4-\lambda)}\right) & a < \frac{\lambda}{2} \\ a\left(1-\frac{a}{\lambda}\right) & \frac{\lambda}{2} \le a \le \frac{\lambda}{2-\lambda} \\ a\frac{1}{2}(1-a) & a > \frac{\lambda}{2-\lambda} \end{cases}.$$

If we solve for the first range when $a < \frac{\lambda}{2}$ and competitive regime prevails, we see that the value that maximizes expression $a\left(\frac{1}{\lambda(4-\lambda)}(3\lambda - a(\lambda+2))\right)$ is $a = \frac{3\lambda}{2\lambda+4}$. However, since $\frac{3\lambda}{2\lambda+4} > \frac{\lambda}{2}$ for any λ the network sets $a = \frac{1}{2}\lambda$ which determines $p_A = \frac{1}{2}$ and $p_B = \frac{1}{2}\lambda$. Moreover, it yields $D_A = \frac{1}{2}$ and $D_B = 0$. For the second range of a, where there is a limit pricing regime, the solution is the same. This strategy generates the following profits for the network

$$\Pi^1(\lambda) = \frac{1}{4}\lambda.$$

The network may also set an access fee $a > \frac{\lambda}{2-\lambda}$ such that in the downstream market there is a monopoly regime. In this case the network chooses a to maximize

$$a\left(\frac{1}{2}(1-a)\right),$$

and then the network sets $a = \frac{1}{2}$, which yields price and demand in the retail market $p_A = \frac{3}{4}$ and $D_A = \frac{1}{4}$. With this strategy the network gets the following profits

$$\Pi^2(\lambda) = \frac{1}{8}.$$

If we compare profits that follow from each strategy we find that

$$\Pi^1(\lambda) \lesseqgtr \Pi^2(\lambda) \text{ as long as } \lambda \lesseqgtr \frac{1}{2},$$

and the statement in the Lemma follows. ■.

Proof of Lemma 4: Assuming non exclusivity, we say that we are in the first regime if all subscribers buy the content, otherwise, we say that we are in the second regime. The problem of the network is to set a to maximize the following function:

$$\Pi(a) = \begin{cases} a\left(1-\frac{a}{\lambda}\right) & a < c\frac{\lambda}{1-\lambda} \\ a(1-(a+c)) & a > c\frac{\lambda}{1-\lambda} \end{cases}.$$

The expression $a = \frac{1}{2}(1-c)$ maximizes $a(1-(a+c))$, and it is the optimal strategy with profits $\left(\frac{1}{2}(1-c)\right)^2$ as $c < \frac{1-\lambda}{\lambda+1}$. The value $a = \frac{1}{2}\lambda$ maximizes $a\left(1-\frac{a}{\lambda}\right)$, and it is the optimal strategy with profits $\frac{1}{4}\lambda$ as $c > \frac{1-\lambda}{2}$. Otherwise the network should set $a = c\frac{\lambda}{1-\lambda}$ which yields profits $c\lambda\frac{1-c-\lambda}{(1-\lambda)^2}$. Thus, the profits of the network in the first regime (all the consumer buy the content) as a function of c and λ are

$$\Pi^3(\lambda, c) = \begin{cases} \left(\frac{1}{2}(1-c)\right)^2 & c < \frac{1-\lambda}{\lambda+1} \\ c\lambda\frac{1-c-\lambda}{(1-\lambda)^2} & c > \frac{1-\lambda}{\lambda+1} \end{cases},$$

and the profits of the network in the second regime (not all consumers buy the content) are

$$\Pi^4(\lambda, c) = \begin{cases} c\lambda\frac{1-c-\lambda}{(1-\lambda)^2} & c < \frac{1-\lambda}{2} \\ \frac{1}{4}\lambda & c > \frac{1-\lambda}{2} \end{cases}.$$

Then, the solution of the content provider depends on the comparison between $\Pi^3(\lambda, c)$ and $\Pi^4(\lambda, c)$.

Note that $Max_c\,\Pi^3(\lambda, c) = \frac{1}{2}(1-\lambda)$ and $\Pi^3\left(\lambda, \frac{1}{2}(1-\lambda)\right) = \frac{1}{4}\lambda$ so that profits $\Pi^3(\lambda, c)$ when $c > \frac{1-\lambda}{\lambda+1} > \frac{1-\lambda}{2}$ are dominated by those of the strategy of setting $a = \frac{1}{2}\lambda$. Similarly, note that when $c < \frac{1-\lambda}{2} < \frac{1-\lambda}{\lambda+1}$, profits $\Pi^3\left(\lambda, \frac{1-\lambda}{2}\right) = \frac{1}{16}(\lambda+1)^2 > \Pi^3\left(\lambda, \frac{1}{2}(1-\lambda)\right) = \frac{1}{4}\lambda$. Consequently, the strategy of setting $a = c\frac{\lambda}{1-\lambda}$ is always dominated.

Finally, we compare profits $\Pi^3(\lambda, c)$ and $\Pi^4(\lambda, c)$ when $\frac{1-\lambda}{2} < c < \frac{1-\lambda}{\lambda+1}$, and it is very easy to show that $\Pi^3(\lambda, c) \gtreqless \Pi^4(\lambda, c)$ if $c \lesseqgtr 1-\sqrt{\lambda}$. ■.

Proof of Lemma 5: If the content provider sets $c > 1-\sqrt{\lambda}$ there will be a positive set of consumers that will only buy the basic service, and will buy the content those consumers such that $\theta(1-\lambda) \geq c$. Therefore, the problem of the provider is to set c to maximize

$$\pi_{cp}(c) = \begin{cases} c\frac{1}{2}(1-c) & c < 1-\sqrt{\lambda} \\ c\left(1-\frac{c}{(1-\lambda)}\right) & c > 1-\sqrt{\lambda} \end{cases}.$$

The value $c = \frac{1}{2}$ maximizes $c\frac{1}{2}(1-c)$, yields profits $\frac{1}{8}$ and satisfies the constraint as $\lambda < \frac{1}{4}$. If $\lambda > \frac{1}{4}$, the $c = 1-\sqrt{\lambda}$ would yield profits $\frac{1}{2}\sqrt{\lambda}\left(1-\sqrt{\lambda}\right)$. Then, if the content provider sets a c such that we are in the first regime (all consumers buy the content), it obtains:

$$\pi^1_{cp}(\lambda) = \begin{cases} \frac{1}{8} & \lambda < \frac{1}{4} \\ \frac{1}{2}\sqrt{\lambda}\left(1-\sqrt{\lambda}\right) & \lambda > \frac{1}{4} \end{cases}.$$

Now, consider that the content provider sets a c such that we are in the second regime (not all the consumer buy the content). The function $c\left(1-\frac{c}{(1-\lambda)}\right)$ is concave and it is maximized for $c = \frac{1-\lambda}{2}$. However, $\frac{1-\lambda}{2}$ is always lower than the constraint which implies that the constrained optimal is $c = 1-\sqrt{\lambda}$. Thus, the profits of the second regime as a function of λ are

$$\pi^2_{cp}(\lambda) = \left(1-\sqrt{\lambda}\right)\left(1-\frac{\left(1-\sqrt{\lambda}\right)}{(1-\lambda)}\right).$$

Then, the solution of the content provider depends on the comparison between $\pi^1_{cp}(\lambda)$ and $\pi^2_{cp}(\lambda)$. It is easy to show that if $\lambda > \frac{1}{4}$ then $\pi^1_{cp}(\lambda) < \pi^2_{cp}(\lambda)$ and the second regime is optimal. If $\lambda < \frac{1}{4}$, then $\pi^1_{cp}(0) - \pi^2_{cp}(0) > 0$, $\pi^1_{cp}\left(\frac{1}{4}\right) - \pi^2_{cp}\left(\frac{1}{4}\right) < 0$ and $\pi^1_{cp}(\lambda) - \pi^2_{cp}(\lambda)$ is decreasing if $\lambda \in [0, \frac{1}{4}]$. Then, $\pi^1_{cp}(\lambda) - \pi^2_{cp}(\lambda) = 0$ has only one root if $\lambda \in [0, \frac{1}{4}]$. There is a $\widehat{\lambda}$ such that $\pi^1_{cp}\left(\widehat{\lambda}\right) - \pi^2_{cp}\left(\widehat{\lambda}\right) = 0 \Leftrightarrow \left(1-\sqrt{\widehat{\lambda}}\right)\left(1-\frac{\left(1-\sqrt{\widehat{\lambda}}\right)}{(1-\widehat{\lambda})}\right) = \frac{1}{8} \Rightarrow \widehat{\lambda} = \frac{33}{128} - \frac{7}{128}\sqrt{17}$. ■

Proof of Lemma 6: We start the proof with a Lemma that presents operators prices. Then we can solve the problem of the network.

Lemma 8 *When $c > 0$, equilibrium prices are the following*

$$p^A(a,c) = \begin{cases} \frac{(3a+2(1-\lambda)-2c)}{4-\lambda} + \frac{c\lambda}{4-\lambda} & a < \frac{\lambda}{2} + \frac{\lambda}{2(1-\lambda)}c \\ \frac{a}{\lambda} - c & \frac{\lambda}{2} + \frac{\lambda}{2(1-\lambda)}c \le a \le \frac{\lambda}{2-\lambda}(1+c) \\ \frac{1}{2}(1+a-c) & a > \frac{\lambda}{2-\lambda}(1+c) \end{cases},$$

$$p^B(a,c) = \begin{cases} \frac{(a(2+\lambda)+\lambda(1-\lambda))}{4-\lambda} + \frac{c\lambda}{4-\lambda} & a < \frac{\lambda}{2} + \frac{\lambda}{2(1-\lambda)}c \\ a & \frac{\lambda}{2} + \frac{\lambda}{2(1-\lambda)}c \le a \le \frac{\lambda}{2-\lambda}(1+c) \end{cases}.$$

Proof: If operator B has a positive demand, equilibrium outcome given a and c is the following

$$p_A = \frac{1}{4-\lambda}(3a + 2(1-\lambda) - 2c) + \frac{c\lambda}{4-\lambda},$$
$$p_B = \frac{(a(2+\lambda) + \lambda(1-\lambda))}{4-\lambda} + \frac{c\lambda}{4-\lambda},$$

and

$$D_A = \frac{(2-a)(1-\lambda) - c(2-\lambda)}{(1-\lambda)(4-\lambda)},$$
$$D_B = \left(\frac{(1-\lambda)(\lambda-2a) + \lambda c}{\lambda(1-\lambda)(4-\lambda)}\right).$$

Then, we use the same procedure that we follow in the proof of Lemma 2 to prove that the ranges of a are given by Figure 5. ■

The problem of the network is to choose, for a given λ and c, the fee, a, that maximizes the function:

$$\Pi(a,c)=\begin{cases} a\left(\frac{3\lambda-(a+c)\lambda-2a}{\lambda(4-\lambda)}\right) & a<\frac{\lambda}{2}+\frac{\lambda}{2(1-\lambda)}c \\ a\left(1-\frac{a}{\lambda}\right) & \frac{\lambda}{2}+\frac{\lambda}{2(1-\lambda)}c\leq a\leq\frac{\lambda}{2-\lambda}(1+c) \\ a\frac{1}{2}(1-a-c) & a>\frac{\lambda}{2-\lambda}(1+c) \end{cases}.$$

We have to solve the problem in two steps. Firstly, we have to analyze the network optimization problem for a given (c,λ) under the constraint that we are in a particular regime (competitive regime characterized by the first case ($a<\frac{\lambda}{2}+\frac{\lambda}{2(1-\lambda)}c$), the limit pricing regime characterized by the second case ($\frac{\lambda}{2}+\frac{\lambda}{2(1-\lambda)}c\leq a\leq\frac{\lambda}{2-\lambda}(1+c)$) and the monopoly regime characterized by the third case ($a>\frac{\lambda}{2-\lambda}(1+c)$)). Then, we will obtain the optimal strategy and profits for every regime. The next step is to analyze what is the optimal regime for a particular combination of (c,λ).

Consider the first constraint, $a<\frac{\lambda}{2}+\frac{\lambda}{2(1-\lambda)}c$, then the network sets $a=\frac{\lambda(3-c)}{2(\lambda+2)}$ as long as $c>\frac{1}{3}(1-\lambda)^2=c_1(\lambda)$ which induces a competitive regime with

$$\begin{aligned} D_A &= \frac{1}{2}\frac{8(1-c)-7\lambda+c\lambda-\lambda^2+c\lambda^2}{(\lambda-1)(\lambda+2)(\lambda-4)} \\ D_B &= \frac{3c+2\lambda-\left(1+\lambda^2\right)}{(1-\lambda)(\lambda+2)(4-\lambda)} \end{aligned}$$

and profits

$$\Pi^{cr}(c,\lambda)=\frac{\lambda}{4}\frac{(3-c)^2}{(\lambda+2)(4-\lambda)}.$$

If $c<c_1(\lambda)$, then the unconstrained optimal fee is larger than the constraint, and the network sets the constraint (which is optimal given the concavity of the problem)

$$a=\frac{\lambda}{2}+\frac{\lambda}{2(1-\lambda)}c \tag{5}$$

which induces a limit pricing regime with

$$D_A=\frac{1}{2}\left(\frac{1-c-\lambda}{1-\lambda}\right)$$

and profits

$$\Pi^{lp}(c,\lambda)=\frac{\lambda}{4}\left(1-\frac{c^2}{(1-\lambda)^2}\right). \tag{6}$$

Along the second range $\frac{\lambda}{2}+\frac{\lambda}{2(1-\lambda)}c\leq a\leq\frac{\lambda}{2-\lambda}(1+c)$ the network sets (5) and then profits are also (6). Notice that the unconstrained optimal will be $\frac{\lambda}{2}$, which jointly with the concavity implies that the optimal solution must be the lowest value of the feasible set. Finally, take the last range $a > \frac{\lambda}{2-\lambda}(1+c)$, then the network sets $a = \frac{1}{2}(1-c)$, which yields

$$\begin{aligned} D_A &= \frac{1}{4}(1-c) \\ \Pi^m(c,\lambda) &= \frac{1}{8}(1-c)^2. \end{aligned}$$

This solution is valid only if the constrained is satisfied. Otherwise, if $c > \widehat{c}(\lambda) = \frac{1}{\lambda+2}(2-3\lambda)$ the network sets $a = \frac{1}{2-\lambda}\lambda(1+c)$, then demand is given by

$$D_A = \frac{1-c-\lambda}{2-\lambda},$$

and profits by this restricted monopoly case

$$\Pi^{rm}(c,\lambda) = \lambda(c+1)\frac{(1-c-\lambda)}{(2-\lambda)^2}. \tag{7}$$

Note that $\widehat{c}(\lambda)$ satisfies $\Pi^m(\widehat{c}(\lambda),\lambda) = \Pi^{rm}(\widehat{c}(\lambda),\lambda)$ and that $\Pi^{cr}(c_1(\lambda),\lambda) = \Pi^{lp}(c_1(\lambda),\lambda)$. The following function

$$c_{21}(\lambda) = \left(\sqrt{2}\right)(1-\lambda)^2\frac{\frac{1}{2}\sqrt{2}-\sqrt{\frac{\lambda^3}{(1-\lambda)^2}}}{\lambda^2+1}$$

satisfies, $\Pi^{lp}(c_{21}(\lambda),\lambda) = \Pi^m(c_{21}(\lambda),\lambda)$.

Since we restrict to $c \geq 0$ then

$$c_2(\lambda) = \begin{cases} c_{21}(\lambda) & \lambda \leq \frac{1}{2} \\ 0 & \lambda > \frac{1}{2} \end{cases}.$$

Similarly, from $\Pi^m(c,\lambda)$ and $\Pi^{cr}(c,\lambda)$ we find

$$c_3(\lambda) = \frac{4\lambda+\lambda^2+\sqrt{2}\sqrt{\frac{\lambda}{(\lambda+2)^3(4-\lambda)}}\left(32-2\lambda^3+24\lambda\right)-8}{\left(\lambda-2\sqrt{2}\right)\left(\lambda+2\sqrt{2}\right)},$$

such that $\Pi^m(c_3(\lambda),\lambda) = \Pi^{cr}(c_3(\lambda),\lambda)$.

First, we show that there exists $\bar{\lambda} \in [0,\frac{1}{2}]$ ($\bar{\lambda} \simeq 0.4$) such that $c_1\left(\bar{\lambda}\right) = c_2\left(\bar{\lambda}\right)$ which follows from the fact that functions $c_1(\lambda)$ and $c_2(\lambda)$ are both decreasing in $\lambda \in \left[0,\frac{1}{2}\right]$, $c_2(0) > c_1(0)$, and $c_2\left(\frac{1}{2}\right) = 0 < c_1\left(\frac{1}{2}\right)$. It implies, that

$$\Pi^{cr}\left(c_1\left(\bar{\lambda}\right),\bar{\lambda}\right) = \Pi^{lp}\left(c_1\left(\bar{\lambda}\right),\bar{\lambda}\right) = \Pi^{lp}\left(c_2\left(\bar{\lambda}\right),\bar{\lambda}\right) = \Pi^m\left(c_2\left(\bar{\lambda}\right),\bar{\lambda}\right). \tag{8}$$

Given that $c_3(\lambda)$ gives us $\Pi^m(c_3(\lambda),\lambda) = \Pi^{cr}(c_3(\lambda),\lambda)$, then $\Pi^m\left(c_3\left(\bar{\lambda}\right),\bar{\lambda}\right) = \Pi^{cr}\left(c_3\left(\bar{\lambda}\right),\bar{\lambda}\right)$, and consequently, at $\bar{\lambda}$, the equality $c_1\left(\bar{\lambda}\right) = c_2\left(\bar{\lambda}\right) = c_3\left(\bar{\lambda}\right)$ is satisfied.

Now, we move to the second step and we analyze the optimal regimes for the network, given a pair (c, λ). Note that, as $\lambda < \bar{\lambda}$, $c_1(\lambda) < c_3(\lambda) < c_2(\lambda) < \widehat{c}(\lambda)$. Given that we know that for a larger c than $c_3(\lambda)$, the competitive regime dominates the monopoly regime, we can ignore $\widehat{c}(\lambda)$, that compares the profits of monopoly with constrained monopoly. This is because both regimes are dominated by the competitive regime for $c > c_3(\lambda)$. Using a similar argument, we can ignore $c_2(\lambda)$ if $\lambda < \bar{\lambda}$, since for $c > c_1(\lambda)$, competitive regime dominate the limit pricing regime, and as we said, for $c > c_3(\lambda)$, the competitive regime dominates the monopoly regime. Finally, for the same token we can ignore $c_1(\lambda)$ if $\lambda < \bar{\lambda}$. Because, for $c < c_2(\lambda)$, the monopoly regime dominates the limit pricing regime, and as we said, for $c < c_3(\lambda)$, competitive regime is dominated by the monopoly regime. Therefore, the only function that we have to consider when $\lambda < \bar{\lambda}$ is $c_3(\lambda)$, which tell us that for low values of c the optimal regime is the monopoly, and for large values of c the optimal regime is the competitive regime.

Consider the range such that $\lambda > \bar{\lambda}$. Along this range it holds that $c_3(\lambda) \leq c_2(\lambda) < c_1(\lambda)$. Then, we can ignore $c_3(\lambda)$ if $\lambda > \bar{\lambda}$. Firstly notice that if $c < c_1(\lambda)$ the competitive regime cannot be induced. Then, if $c > c_1(\lambda)$, the competitive regime dominates the limit pricing regime and the monopoly regime (because for $c > c_2(\lambda)$ and the monopoly regime is dominated by the limit pricing regime). If $c_2(\lambda) < c < c_1(\lambda)$ the limit pricing regime dominates, since for $c_2(\lambda) < c$ limit pricing dominates monopoly. Finally, for $c < c_2(\lambda)$ the monopoly regime dominates for the definition of $c_2(\lambda)$ and the fact, that the competitive regime is not feasible. Finally, we can also ignore $\widehat{c}(\lambda)$ since it is always larger than $c_2(\lambda)$, and for $c > c_2(\lambda)$, the monopoly regime is dominated by the limit pricing regime. Then, $c_2(\lambda)$ and $c_1(\lambda)$ are enough to describe the network optimal regime strategies when $\lambda > \bar{\lambda}$. Consequently, the three regions in the Lemma are defined. ■

Proof of Lemma 7: Provider chooses c to maximize the expression

$$cD_A(c) + (p_A(c) - a(c)) D_A(c) - (p_B(c) - a(c)) D_B(c).$$

Consider $\lambda > \bar{\lambda}$. The content provider gets the higher profits that a competitive regime can generate by setting

$$\bar{c}(\lambda) = 9\lambda \frac{1-\lambda}{16 + 21\lambda - \lambda^3}$$

as long as $\bar{c}(\lambda)$ is higher than $c_1(\lambda)$ and it yields profits

$$\pi_{cp}^{cr}(\bar{c}(\lambda)) = \frac{1}{4}(\lambda-1)\frac{-48\lambda-9\lambda^2+4\lambda^3-64}{(\lambda-4)(-21\lambda+\lambda^3-16)}.$$

Otherwise, the content provider may induce the limit pricing regime by setting $c_1(\lambda)$ which yields

$$\pi_{cp}^{lp}(c_1(\lambda)) = \frac{1}{36}(1-\lambda)(\lambda+2)(4-\lambda).$$

In particular, there exists $\bar{\lambda} < \lambda_0 < \frac{1}{2}$ such that $\bar{c}(\lambda_0) = c_1(\lambda_0)$. The content provider can also induce a limit pricing by setting $c_2(\lambda)$ which yields the higher profits that a limit pricing regime can generate:

$$\pi_{cp}^{lp}(c_2(\lambda)) = \begin{cases} \frac{1}{4}(1-\lambda)\frac{2\lambda+2\sqrt{2}\sqrt{\frac{\lambda^3}{(\lambda-1)^2}}+\lambda^2-2\lambda^3+\lambda^4-4\sqrt{2}\lambda\sqrt{\frac{\lambda^3}{(\lambda-1)^2}}+2\sqrt{2}\lambda^2\sqrt{\frac{\lambda^3}{(\lambda-1)^2}}}{(\lambda^2+1)^2} & \lambda \leq \frac{1}{2} \\ \frac{1}{4}(1-\lambda) & \lambda > \frac{1}{2} \end{cases}.$$

Note that $\pi_{cp}^{lp}(c_2(\lambda)) \geq \pi_{cp}^{lp}(c_1(\lambda))$ along the relevant range $\lambda \epsilon (\bar{\lambda}, \lambda_0)$ and $\pi_{cp}^{lp}(c_2(\lambda)) > \pi_{cp}^{cr}(\bar{c}(\lambda))$ as $\lambda \epsilon (\lambda_0, \frac{1}{2})$. Consequently, as $\lambda \epsilon (\bar{\lambda}, \frac{1}{2})$ the provider will set $c_2(\lambda)$.

Now, notice that there exists $\lambda_1 \epsilon (\frac{1}{2}, 1)$ such that as $\lambda \epsilon (\frac{1}{2}, \lambda_1)$ then $\pi_{cp}^{lp}(c_2(\lambda)) - \pi_{cp}^{cr}(\bar{c}(\lambda)) > 0$ and as $\lambda \epsilon (\lambda_1, 1)$ then $\pi_{cp}^{lp}(c_2(\lambda)) - \pi_{cp}^{cr}(\bar{c}(\lambda)) < 0$. Therefore, as $\lambda \epsilon (\frac{1}{2}, \lambda_1)$ the provider will set $c_2(\lambda) = 0$, and as $\lambda \epsilon (\lambda_1, 1)$ the provider will set $\bar{c}(\lambda)$.

Finally, as $\lambda < \bar{\lambda}$, the content provider chooses a competitive regime by setting $c_3(\lambda)$ (strategies involving $c \gtrless c_3(\lambda)$ are dominated). This strategy generates

$$\begin{aligned}\pi_{cp}^{cr}(c_3(\lambda)) &= \frac{\lambda(\lambda(\lambda(\lambda(\lambda(\lambda+2)-7)-15)+44)+56)}{(2\sqrt{2}-\lambda)^2(\lambda+2\sqrt{2})^2(\lambda+2)(\lambda-1)} + \\ &\quad \frac{(\lambda(\lambda(\lambda(\lambda(\lambda(3-\lambda)+30)+68)+24)-192)-256)\sqrt{2}\sqrt{\frac{\lambda}{(\lambda+2)^3(4-\lambda)}}}{(2\sqrt{2}-\lambda)^2(\lambda+2\sqrt{2})^2(\lambda+2)(\lambda-1)}.\end{aligned}$$

Proof of Proposition 4:

Note that the inequality $\pi_{cp}^{cr}(\bar{c}(\lambda)) > \pi_{cp}^{NE}$ is satisfied for any λ, and that the inequality $\pi_{cp}^{lp}(c_2(\lambda)) > \pi_{cp}^{NE}$ is also satisfied for the relevant range $\lambda \epsilon (\bar{\lambda}, \lambda_2)$.

If $\lambda < \bar{\lambda}$, there is a λ^* such that $\pi_{cp}^{NE}(\lambda^*) - \pi_{cp}^{cr}(c_3(\lambda^*)) = 0 \Rightarrow \lambda^* \simeq 0.36$, $\pi_{cp}^{NE} - \pi_{cp}^{cr}(c_3(\lambda)) > 0$ as $\lambda < \lambda^*$ and $\pi_{cp}^{NE} - \pi_{cp}^{cr}(c_3(\lambda)) < 0$ as $\lambda > \lambda^*$. In particular, λ^* exists because $\pi_{cp}^{NE}(\lambda)$ and $\pi_{cp}^{cr}(c_3(\lambda))$ are concave, $\lambda^{*NE} = Max_\lambda\ \pi_{cp}^{NE}(\lambda) < \lambda^{*c_3} = Max_\lambda \pi_{cp}^{cr}(c_3(\lambda))$, $\pi_{cp}^{NE}(\lambda^{*NE}) > \pi_{cp}^{cr}(c_3(\lambda^{*c_3}))$, $\pi_{cp}^{NE}(\lambda) - \pi_{cp}^{cr}(c_3(\lambda)) > 0$ as $\lambda \epsilon (0, \lambda^{*NE})$, $\pi_{cp}^{NE}(\lambda) - \pi_{cp}^{cr}(c_3(\lambda))$ increasing as λ

$\in \left(0, \lambda^{*NE}\right)$, and $\pi_{cp}^{NE}\left(\bar{\lambda}\right) - \pi_{cp}^{cr}\left(c_3\left(\bar{\lambda}\right)\right) < 0$. Therefore $\pi_{cp}^{NE}(\lambda) - \pi_{cp}^{cr}(c_3(\lambda)) = 0$ has only one root if $\lambda \in [0, \bar{\lambda}]$.

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