Net Neutrality and Access Regulation

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Abstract

In this paper we analyze the interplay between access regulation and net neutrality in the market for Internet access. We consider two Internet Service Providers (ISPs) which act as platforms between Internet users and content providers (CPs). One of the ISPs is vertically integrated and provides access to the other (non-integrated) ISP. We show that a lower access price either increases or decreases the ISPs' incentives to deviate from net neutrality (i.e. to charge CPs positive termination fees), due to the coexistence of two opposite effects: a complementarity effect and a waterbed effect.

Keywords: Net neutrality; Access regulation; Internet access; Two-sided markets.

JEL codes: L13; L51; L52; L96.

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1 Introduction

The Internet can be described as a platform that puts together end users and Content Providers (CPs). The *de facto* rule that Internet Service Providers (ISPs) cannot discriminate between the information packets sent by CPs has long prevailed. This rule implied in particular that CPs paid the ISP that hosted their servers but not the other ISPs carrying their traffic (no termination fee), that CPs were all offered the same quality of service (no discrimination), and that ISPs could not prioritize certain types of traffic (no prioritization). Recently, some ISPs have strayed from these so-called "net neutrality" rule on the grounds that they have to invest in network infrastructures to cope with the dramatic increase of Internet traffic, and that CPs should bear a share of the investment cost. Since net neutrality is regarded as one of the founding principles of the Internet, heated debates have ensued.

The debates on net neutrality have revolved around two main issues: whether a deviation from net neutrality would improve or harm welfare, and whether specific regulations are necessary to keep the Internet neutral. A recent academic literature has addressed the former issue by studying the impact on welfare of various deviations from net neutrality such as termination fees, discrimination and prioritization. Although the literature has analyzed the ISPs' incentives to deviate from net neutrality, the issue of the regulatory measures that would ensure that the Internet remains neutral has received less attention.

One such regulatory instrument is access regulation, i.e. the requirement for vertically integrated ISPs to provide non-integrated ISPs with an access to their essential facilities, and in particular to their "last mile" network. It has often been argued that a tight regulation of access would strengthen competition between ISPs, which in turn would reduce their incentives to deviate from net neutrality. This argument was put forth by E. Porter in the New York Times, who argued that "[w]ith fewer competitors in the way, broadband's gatekeepers will face less resistance to a strategy of carving special lanes out of the Internet".[1]

However, this kind of argument ignores the complex interplay between the competition among ISPs and their incentives to deviate from net neutrality. On the one hand, one could argue that without market power deviations from net neutrality would not be sustainable.[2] On the other hand,

[1]E. Porter, "Keeping the Internet Neutral". *The New York Times*, May 8, 2012.

[2]As stressed by N. Economides, "[i]n a truly competitive market such discrimination would lead to a loss of

stronger competition for Internet users may raise ISPs' incentives to seek additional revenues from the content side.

In this paper we consider a vertically integrated ISP that gives access to her "last-mile" network to a non-integrated ISP. Both ISPs are platforms that put together end users and CPs. Each ISP charges a subscription fee to her users and may also charge a termination fee to CPs. We interpret a positive termination fee as a departure from net neutrality. We then study whether a tighter access regulation helps keeping the Internet neutral by analyzing the relation between a regulated access price and unreguled termination fees.

Our findings challenge the assumption that a low access price would keep the Internet neutral. We show that the relation between the access price and the termination fees may be either positive or negative, due to the coexistence of two opposite effects: a complementarity effect and a waterbed effect. On the one hand, there is a positive relation between the access price and the termination fee set by the non-integrated ISP, given the termination fee set by the integrated ISP (complementarity effect). On the other hand, there is a negative relation between the access price and the termination fee set by the integrated ISP, given the termination fee set by the non-integrated ISP (waterbed effect).

Our paper belongs to the emerging literature on net neutrality (see Krämer, Wiewiorra and Weinhardt 2012 for a review). Most of this literature considers an ISP under monopoly and studies whether allowing her to deviate from net neutrality improves or harms welfare. In the papers by Altman, Legout and Xu (2011), Economides and Tåg (2012) and Musacchio, Schwartz and Walrand (2009) a deviation from net neutrality occurs when the ISPs charge not only the end users but also the content providers (two-sided payments).[3] In Cheng, Bandyopadhyay and Guo (2011), Choi and Kim (2010), Economides and Hermalin (2012), Krämer and Wiewiorra (2012) and Reggiani and Valletti (2011), net neutrality is defined as a regime where traffic prioritization is banned. No general conclusion can be drawn from these papers, and it appears that net neutrality may either increase or decrease welfare, depending in particular on the intensity of the cross-group externalities.

Bourreau, Kouranti and Valletti (2012), Choi, Jeon and Kim (2011), Economides and Tåg (2012), Hermalin and Katz (2007) and Njoroge, Ozdaglar, Stier-Moses and Weintraub (2012) consider com-

market share and profit to rival providers who did not discriminate". N. Economides, "Net neutrality required to spur innovation". *The Financial Times*, November 5, 2009.

[3]In Musacchio *et al.* (2009), there are several ISPs but they are local monopolies, not competitors.

petition between ISPs. However, our paper differs from these papers in several aspects. First, they consider the competition between symmetric vertically integrated ISPs, whereas we consider an asymmetric market with a vertically integrated and a non-integrated ISP. More fundamentally, the purpose of these papers is to study whether allowing deviations from net neutrality harms or improves welfare. By contrast, our main goal is to study how the incentives to deviate from net neutrality are affected by access regulation and the intensity of competition. From this respect, Choi *et al.* (2011) is the closest paper to ours. Indeed, Choi *et al.* (2011) consider two interconnected ISPs, and examine how the access charge affects their incentives to deviate from net neutrality. Nevertheless, they consider two-way access, i.e. reciprocal access between vertically integrated ISPs, whereas we focus on one-way access between a vertically integrated ISP and a non-integrated ISP.

Our paper is also related to the literature on access regulation and infrastructure investment (see Cambini and Jiang 2009 for a review). This literature indicates that a low access price strengthen competition between ISPs, which in turn improves welfare (for a given level of investment).[4] Our contribution is two analyze whether this result holds when the ISPs are platforms that put end users and CPs together, and to study how access regulation affects welfare through its impact on the ISPs' incentives to deviate from net neutrality.

The reminder of the paper is organized as follows. We introduce the model in Section 2. In Section 3 we derive the equilibrium in the market for Internet access. In Section 4 we examine a benchmark case where both the access price to the integrated ISP's infrastructure and the termination fees are regulated. In Section 5 we study the relation between a regulated access price and unregulated termination fees. Section 6 concludes.

2 The model

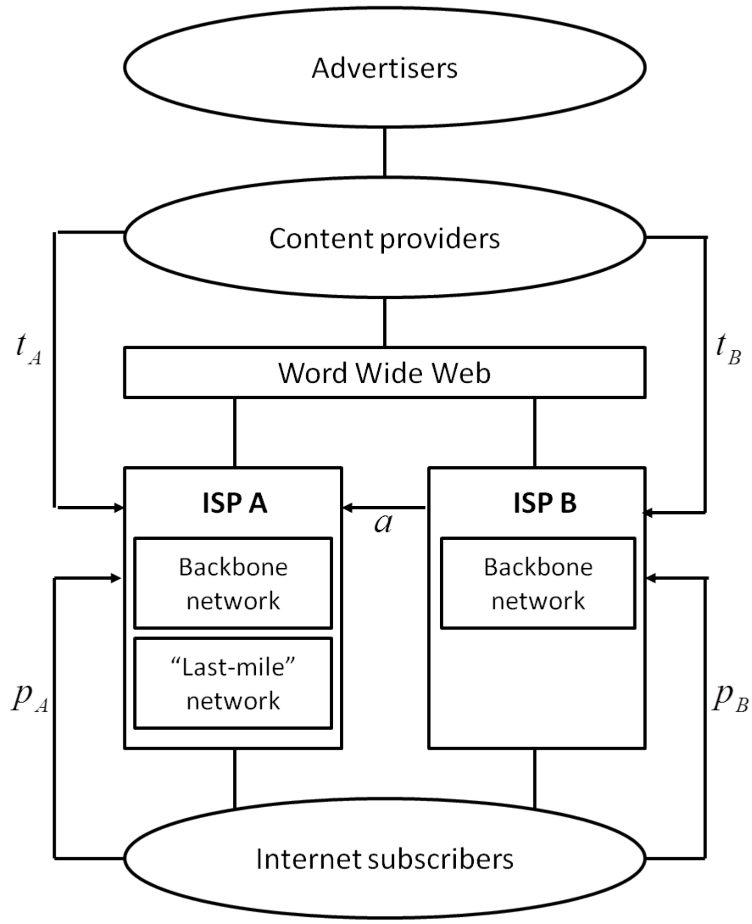
Two Internet Service Providers, ISP A and ISP B, act as platforms between end users and Content Providers (CPs). The ISPs charge subscription fees (p_A and p_B) to Internet users and termination fees ($t_A \geq 0$ and $t_B \geq 0$) to CPs. ISP A is vertically integrated and provides ISP B with access to her "last-mile" network at a per-unit access fee a.[5] Finally, CPs incur fixed costs to produce content

[4] However, the literature also shows that a low access price may lessen, delay or discourage infrastructure investment.

[5] Different access offers exist, such as local loop unbundling and bitstream access. See Bourreau and Doğan (2004) for details.

and deliver it on the Web. CPs can provide content to a single ISP (single-homing) or to both ISPs (multi-homing). They derive revenues from advertising, and Internet users access content for free. The market structure is illustrated in Figure 1.

Figure 1: The market for Internet access



2.1 Internet users

We adopt the competitive setting of quantity competition with quality differentiation from Katz and Shapiro (1985). The indirect utility of a consumer of type θ who subscribe to ISP $i \in \{A, B\}$ is $U_{\theta,i} = \theta + \beta_C n_i - p_i$, where θ represents consumer's utility when there is no content in the network,[6] $\beta_C > 0$ is a parameter that reflects the degree of externality from the content side to the service

[6]When $n_i = 0$, the ISP provides a minimal set of communications services, such as email.

side, and $n_i \geq 0$ is the number of CPs that make their content available at ISP i. Consumers' types are uniformly distributed over $(-\infty, \alpha]$. Both ISPs are active in the market if their "quality-adjusted prices" are the same, i.e. if $p_A - \beta_C n_A = p_B - \beta_C n_B$. Then, $\alpha - (p_i - \beta_C n_i)$ potential users have a positive utility, and the total number of Internet subscribers is $q = q_A + q_B = \alpha - (p_i - \beta_C n_i)$ where q_A and q_B are the number of users of ISP A and ISP B, respectively. Therefore, the inverse demand for ISP $i \in \{A, B\}$ is

$$p_i = \alpha + \beta_C n_i - q_A - q_B. \quad (1)$$

2.2 Internet Service Providers

For the vertically integrated ISP, the marginal cost of providing Internet services is $c_n + c_r$, where c_n and c_r are the marginal cost of the last-mile network and the retail marginal cost, respectively. For the non-integrated ISP, the marginal cost of providing services is $a + c_r$, because she has to pay the access fee a to her rival. We assume that the cost of routing content through their backbone network is zero for both ISPs. The profits of ISPs A and B are then

$$\pi_A = (p_A - c_n - c_r)q_A + (a - c_n)q_B + t_A n_A \quad (2)$$

and

$$\pi_B = (p_B - a - c_r)q_B + t_B n_B, \quad (3)$$

respectively. The first term in (2) and (3) represents the ISPs' retail profits. The second term in (2) represents ISP A's access profit. Finally, the last terms represent the ISPs' profits from terminating CPs' data traffic on their networks.

2.3 Content Providers

As Economides and Tåg (2012), we assume that each CP provides a specific content which is different from the content offered by the other CPs (i.e., the CPs are independant monopolists). Each CP is characterized by the fixed cost y she incurs for producing content and delivering it on the Web. We assume that y is uniformly distributed on $[0, \infty)$. CP y has to pay a termination fee t_i to makes her content available at ISP i. She then obtains an advertising revenue $\beta_S q_i$ where β_S is the net advertising revenue per Internet subscriber.[7] β_S can also be interpretated as the degree of externality from the content side to the services side. We make the following assumption on the levels of externality.

Assumption 1. $\beta_C \beta_S < 3/2$.

This assumption ensures that the equilibrium of the game is stable, as we will show in Section 3.

2.4 Timing of the game

We study two different cases, depending on whether termination fees are regulated or left to the market. In Section 4 we start by analyzing a "full regulation" benchmark, where the regulator sets both the access price and the termination fees in a first stage. In a second stage, the ISPs set the subscription fees; simultaneously, CPs decide whether to enter the market or not, and Internet users choose which ISP to subscribe to (if any).

In Section 5 we study the case where the termination fees are not regulated. The timing of the game is then modified as follows. First, the regulator sets the access price. Second, the ISPs set the termination fees. Third, and finally, the ISPs, CPs and Internet users make their decisions as in the full regulation benchmark.

3 Equilibrium in the market for Internet access

In this section we determine the equilibrium in the last stage of the game where the ISPs set subscription fees, and CPs and Internet users decide whether or not to connect to the Internet platforms.

[7] Our model assumes that the prices charged by the ISPs to both sides of the market (i.e., p_i and t_i) are fixed membership fees. This assumption is also made by Bourreau *et al.* (2012), Choi and Kim (2010), Choi *et al.* (2011), Economides and Hermalin (2012), Economides and Tåg (2012), Njoroge *et al.* (2012), and Reggiani and Valletti (2011). By contrast, Musacchio *et al.* (2009) and Cheng *et al.* (2011), assume that ISPs charge variable usage fees to both sides. Finally, Altman *et al.* (2011), Hermalin and Katz (2007), and Krämer and Wiewiorra (2012) assume that Internet users are charged fixed membership fees and CPs are charged variable usage fees.

Whereas ISPs usually charge fixed membership fees to their subscribers, the assumption that they also charge fixed fees to the CPs essentially aims at keeping the analysis tractable.

3.1 Service side

The ISPs maximize their profits, which are given by (2) and (3). Solving for the first order conditions with respect to q_A and q_B, we find the optimal quantities for expected numbers of CPs n_A^e, n_B^e.[8] We have:

$$q_A(n_A^e, n_B^e) = \frac{1}{3}(\alpha + a - c_r - 2c_n + 2\beta_C n_A^e - \beta_C n_B^e), \tag{4}$$

and

$$q_B(n_A^e, n_B^e) = \frac{1}{3}(\alpha - 2a - c_r + c_n + 2\beta_C n_B^e - \beta_C n_A^e). \tag{5}$$

The total number of Internet users is then

$$q(n_A^e, n_B^e) = \frac{1}{3}(2\alpha - a - 2c_r - c_n + \beta_C(n_A^e + n_B^e)). \tag{6}$$

3.2 Content side

Once she has paid the entry cost y, CP y can decide to singlehome, to multihome, or to stay out of the market. She decides to multihome, that is, to make her content available at both ISPs, if and only if $\beta_S q_i - t_i \geq 0$ for $i \in \{A, B\}$. We argue that this condition always holds in equilibrium. Indeed, as all CPs have the same net utility of joining ISP i, either all of them connect to ISP i or none. Since the marginal cost of routing content is zero for the ISP, she is always better-off having the CPs on board, and she therefore sets $t_i \geq \beta_S q_i$. This proves that the CPs multihome. The profit of CP y, for an expected total number of Internet users $q^e = q_A^e + q_B^e$, is then

$$\pi_y = \beta_S q^e - t_A - t_B - y. \tag{7}$$

Therefore, the number of CPs $n(q^e)$ is determined by $\pi_y = 0$, and we find that

$$n(q^e) = \beta_S q^e - t_A - t_B. \tag{8}$$

[8] The second order conditions are satisfied, as $\partial^2 \pi_A / \partial q_A^2 = \partial^2 \pi_B / \partial q_B^2 = -2 < 0$.

Since the same quantity of content is available at both ISPs, from (6), the total number of Interner users can be rewritten as

$$q(n^e) = \frac{1}{3}(2\alpha - a - 2c_r - c_n + 2\beta_C n^e), \tag{9}$$

where n^e is the expected number of CPs, and, from (1), the price of Internet services is

$$p_A = p_B = p = \alpha + \beta_C n^e - q(n^e). \tag{10}$$

From (8), an additional Internet subscriber entails entry of β_S additional CPs. Since additional contents raise Internet users' utility, from (9), it leads to $\beta_S \times 2\beta_C/3$ additional Internet subscribers, which in turn implies entry from $(\beta_S)^2(2\beta_C/3)$ additional CPs, etc. Repeating this reasoning an infinite number of times we find that there is a multiplier μ such that the number of Internet subscribers is raised by μ if a CP enters the market, and vise versa, where

$$\mu = \frac{1}{1 - 2\beta_S\beta_C/3}.$$

3.3 Fullfiled expectations equilibrium

The fulfilled expectations equilibrium is found by solving the system formed by (8) and (9). For given access price and termination fees, the equilibrium number of CPs and number of Internet users are

$$\widetilde{n} = [2\alpha\beta_S - 3(t_A + t_B) - \beta_S(a + 2c_r + c_n)]\,\mu/3, \tag{11}$$

and

$$\widetilde{q} = [2\alpha - 2\beta_C(t_A + t_B) - a - 2c_r - c_n]\,\mu/3, \tag{12}$$

respectively. Assumption 1, ensures that the equilibrium is stable, i.e. that, from (8) and (9), $n'q' < 1$.[9]

[9]Assumption 1 also implies that the multiplier μ is positive.

From (4) and (5), ISP A and IPS B's numbers of users are

$$\widetilde{q_A} = [\alpha + a(1 - \beta_S\beta_C) - \beta_C(t_A + t_B) - c_n(2 - \beta_S\beta_C) - c_r]\, \mu/3, \tag{13}$$

and

$$\widetilde{q_B} = [\alpha - a(2 - \beta_S\beta_C) - \beta_C(t_A + t_B) + c_n(1 - \beta_S\beta_C) - c_r]\, \mu/3. \tag{14}$$

Finally, from (10), the price of Internet services is

$$\widetilde{p} = [\alpha + a(1 - \beta_S\beta_C) - \beta_C(t_A + t_B) + c_n(1 - \beta_S\beta_C) + 2c_r(1 - \beta_S\beta_C)]\, \mu/3. \tag{15}$$

4 A benchmark: full regulation

In this section we study a benchmark where both the access price and the termination fees are regulated. In Sections 4.1 and 4.2 we characterize the impact of the access price and of termination fees on quantities and prices. Using this benchmark, in Section 4.3 we show that welfare decreases with the termination fees and the access price.

4.1 The impact of termination fees on quantities and prices

We start by determining the effect of termination fees on the number of CPs and the number of users. For a given number of Internet users, the CPs' profits and therefore the number of active CPs decrease with the termination fees (see (7) and (8)). The externality from the content side to the service side implies that Internet users' utility decreases when the number of CPs is reduced. As a consequence, the number of Internet users also decreases with the termination fees (see (9)).

The relation between the termination fees and the Internet subscription fee is a priori ambiguous. First, there is a quality degradation effect. Higher termination fees reduce entry from CPs, which in turn decreases users' utility from Internet access and lowers the subscription fee. Second, there is an externality effect. Since higher termination fees reduce the number of CPs, they also reduce the number of users, which in turn raises the subscription fee. We find that the former effect always dominates, and that the Internet subscription fee always decreases with the termination fees.

This analysis is summarized with the following result.

Lemma 1. *The total number of Internet users, the number of users of each ISP, the number of CPs and the Internet subscription fee decrease with the termination fees.*

Proof. From (11), (12) and (15), we find that

$$\frac{\partial \widetilde{n}}{\partial t_i} = -\mu < 0, \ \frac{\partial \widetilde{q}_i}{\partial t_i} = -\beta_C \mu/3 < 0, \ \frac{\partial \widetilde{q}}{\partial t_i} = -2\beta_C \mu/3 < 0, \text{ and } \frac{\partial \widetilde{p}}{\partial t_i} = -\beta_C \mu/3 < 0.$$

□

4.2 The impact of the access price on quantities and prices

The access price has two effects on the number of Internet users, a direct service side effect and an indirect content side effect.

For a given number of CPs, from equations (4), (5) and (6), an increase in the access price increases the number of users of the vertically integrated ISP, and lowers the number of users of the non-integrated ISP as well as the total number of users (direct "service side" effect). At the same time, due to the externalities, a lower number of Internet users decreases the number of CPs, which in turn reduces the number of users of both ISPs, etc. (indirect "content side" effect).

For the non-integrated ISP, the direct service side effect and the indirect content side effect are mutually reinforcing, and an increase in the access price therefore results in a decrease in her number of users. For the integrated ISP, the direct service side effect and the indirect content side effect work in opposite directions. If the network effects are of low magnitude (i.e., $\beta_S \beta_C < 1$), the service side effect dominates, and the number of users of ISP A increases with the access price, as in the literature on access regulation. However, if the network effect are strong (i.e., $\beta_S \beta_C > 1$), then the number of users of ISP A decreases with the access price. Finally, we find that the total number of users decreases with the access price.

An increase in the access price has also a positive service side effect and a negative content side effect on the Internet subscription fee. On the one hand, as an increase in the access price reduces the total number of users, it also raises the subscription fee. On the other hand, it reduces the number of CPs, which in turn lowers the Internet subscription fee. If the network effects are weak (i.e., $\beta_S \beta_C < 1$), the former effect dominates, and the Internet subscription fee increases with the access price, as in the literature on access regulation. Otherwise, it decreases.

The following result summarizes this analysis.

Lemma 2. *The total number of Internet users, the number of users of the non-integrated ISP and the number of CPs decrease with the access price. If the network effects are weak (i.e., $\beta_S\beta_C < 1$), the Internet subscription fee and the number of users of the integrated ISP increase with the access price. Otherwise, they decrease with the access price.*

Proof. From (11), (12) and (14) we have

$$\frac{\partial \widetilde{n}}{\partial a} = -\beta_S\mu/3,\ \frac{\partial \widetilde{q}}{\partial a} = -\mu/3 < 0 \text{ and } \frac{\partial \widetilde{q_B}}{\partial a} = -(2-\beta_S\beta_C)\mu/3 < 0. \tag{16}$$

From (13) and (15)

$$\frac{\partial \widetilde{q_A}}{\partial a} = (1-\beta_S\beta_C)\mu/3 \text{ and } \frac{\partial \widetilde{p}}{\partial a} = (1-\beta_S\beta_C)\mu/3. \tag{17}$$

and therefore $\partial\widetilde{q_A}/\partial a > 0$ and $\partial\widetilde{p}/\partial a > 0$ iff $\beta_S\beta_C < 1$. □

The impact of the access charge and of the termination fees on the number of CPs, the number of Internet users and the Internet subscription fee is summarized in Table 1.

Table 1: Effect of access price and termination fees on quantities and prices

	Termination fee	Access price
Number of users of ISP A	-	+ if $\beta_S\beta_C < 1$, - otherwise
Number of users of ISP B	-	-
Total number of Internet users	-	-
Number of CPs	-	-
Internet subscription fee	-	+ if $\beta_S\beta_C < 1$, - otherwise

4.3 The regulator's decision

Total welfare is defined as the sum of welfare on the service side and welfare on the content side. From Lemma 1, an increase in the access price or in the termination fees reduces CPs' individual profits as well as the number of active CPs, which lowers welfare on the content side. A decrease in the number of CPs also harms welfare on the service side. An increase in the access price or in the termination fee moreover lowers the number of Internet users, which also reduces welfare on the service side. Hence, we can state the following result.

Proposition 1. *In the full regulation benchmark, the regulator sets the minimum access price and termination fees, compatible with each ISP having a positive number of users and with a positive number of CPs.*

Proof. Welfare on the service side is $W_S = \widetilde{p}.\widetilde{q} + \widetilde{q}^2/2 + (t_A + t_B)\widetilde{n}$, while welfare on the content side is $W_C = \widetilde{n}\widetilde{q}\beta_S - \widetilde{n}(t_A + t_B) - \widetilde{n}^2$. Total welfare is therefore $W = W_S + W_C = \widetilde{n}.\widetilde{q}\beta_S - \widetilde{n}^2/2 + \widetilde{p}.\widetilde{q} + \widetilde{q}^2/2$. A marginal increase in the access price or in the termination fees has the following effect on welfare:

$$\frac{dW}{dx} = \underbrace{\frac{\partial\widetilde{n}}{\partial x}\beta_S\widetilde{q} + \frac{\partial\widetilde{q}}{\partial x}\beta_C\widetilde{q} - \frac{\partial\widetilde{n}}{\partial x}\widetilde{n}}_{=\triangle_C<0} + \underbrace{\frac{\partial\widetilde{q}}{\partial x}\widetilde{p} + \frac{\partial\widetilde{q}}{\partial x}\widetilde{q} + \frac{\partial\widetilde{p}}{\partial x}\widetilde{q}}_{=\triangle_S<0}, \tag{18}$$

where $x \in \{a, t_A, t_B\}$. In equation (18), $\triangle_C$ represents the impact of access or termination fees on welfare on the content side, and $\triangle_S$ the impact of these fees on welfare on the service side.[10] We find that $\triangle_C < 0$, as $(\partial q/\partial x)\beta_C q < 0$ (from Table 1), and $(\partial\widetilde{n}/\partial x)\beta_S\widetilde{q} - (\partial\widetilde{n}/\partial x)\widetilde{n} = (\partial\widetilde{n}/\partial x)(t_A + t_B) < 0$ (from (11) and (12)).

Since $\partial\widetilde{q}/\partial x < 0$, $\triangle_S < 0$ is immediate if $\partial\tilde{p}/\partial x < 0$. However, from Lemma 2 we can have $\partial\tilde{p}/\partial x > 0$. In this case, raising the access price or the termination fees has opposite effects on welfare on the service side. On the one hand, it lowers the number of CPs and the number of Internet users, which in turn reduces welfare (this corresponds to the first two terms in $\triangle_S$). On the other hand, it increases the Internet subscription fee, which in turn increases welfare, which corresponds to the last term in $\triangle_S$. However, from (16) and (17), $\partial\tilde{p}/\partial a < -\partial\tilde{q}/\partial a$ which means that the former effect always dominates the latter, and that $\triangle_S < 0$. □

5 Access price regulation with unregulated termination fees

While access prices to the last-mile networks are regulated in most OECD countries (with the notable exception of the US), termination fees are (usually) not. The idea that promoting competition through access regulation helps keeping the Internet neutral may explain this situation. In this section we analyze the relation between a regulated access price and unregulated termination fees.[11]

[10] Strictly speaking, the effects of a variation in t_A or t_B on welfare on the content and on the service side are $\partial W_C/\partial t_i = \triangle_C - \tilde{n}$ and $\partial W_S/\partial t_i = \triangle_S + \tilde{n}$, respectively. However, $\tilde{n}$ is just a transfer from the service side to the content side, and it has no impact on the total welfare.

[11] The other case, where the access price would be unregulated while termination fees would be regulated, does not seem relevant, given the current regulatory practice.

In Section 5.1 we study how the ISPs set their termination fees for a given access charge set by the regulator. In Section 5.2 we analyze how the access price affects these termination fees, and in Section 5.3 we characterize the impact of the access price on welfare.

5.1 The unregulated termination fees

At the third stage of the game, the ISPs set the subscription fees, and CPs and Internet users make their decisions. The equilibrium of this subgame is given in Section 3. At the second stage, the ISPs observe the access price chosen by the regulator and set their termination fees. Before determining the equilibrium of the subgame, we start by discussing the trade-offs that the two ISPs face when they set the termination fees.

The impact of a marginal increase in the termination fee t_A on the profit of the vertically integrated ISP (ISP A), given the termination fee t_B set by her rival is

$$\frac{d\pi_A}{dt_A} = \underbrace{\widetilde{q_A}\frac{\partial \widetilde{p}}{\partial t_A} + (\widetilde{p} - c_n - c_r)\frac{\partial \widetilde{q_A}}{\partial t_A}}_{=\triangle_R^A<0} + \underbrace{(a - c_n)\frac{\partial \widetilde{q_B}}{\partial t_A}}_{=\triangle_W^A<0} + \underbrace{\frac{\partial \widetilde{n}}{\partial t_A}t_A + \widetilde{n}}_{=\triangle_T^A>0 \text{ then } <0}\ . \tag{19}$$

Equation (19) shows that ISP A faces the following trade-offs. First, an increase in t_A lowers her retail profit because it decreases her revenue per Internet user ($\partial\widetilde{p}/\partial t_A < 0$ from Lemma 1) and her number of users ($\partial\widetilde{q_A}/\partial t_A < 0$). This corresponds to the first term in (19), which is therefore negative. The second term in (19) is also negative; it means that an increase in t_A reduces ISP A's profit from access, because it leads to less active CPs and hence reduces the number of Internet users of ISP B (we have $\partial\widetilde{q_B}/\partial t_A < 0$ from Lemma 1). Finally, the termination profit first increases and then decreases with t_A. On the one hand, a higher termination fee decreases the number of CPs, which reduces termination profit; on the other, it increases the revenue per CP. ISP A therefore faces a standard revenue-quantity trade-off (from Lemma 1, $\widetilde{n} \geq 0$ and $\partial\widetilde{n}/\partial t_A < 0$), and $\triangle_T^A$ is positive for low values of t_A and negative otherwise.

The trade-offs faced by the non-integrated ISP (ISP B) are similar, except that she does not earn any access revenues. A marginal increase in t_B has the following impact on ISP B's profit:

$$\frac{d\pi_B}{dt_B} = \underbrace{\widetilde{q_B}\frac{\partial \widetilde{p}}{\partial t_B} + (\widetilde{p} - c_n - c_r)\frac{\partial \widetilde{q_B}}{\partial t_B}}_{=\triangle_R^B<0} + \underbrace{\frac{\partial \widetilde{n}}{\partial t_B} t_B + \widetilde{n}}_{=\triangle_T^B>0 \text{ then } <0} . \tag{20}$$

An increase in t_B reduces ISP B's retail profit, while it increases her termination profit for low values of t_B and decreases it otherwise ($\triangle_R^B < 0$ and $\triangle_T^B$ can be either positive or negative).

If the second order conditions are satisfied, ISP i's best reply to the termination fee t_j set by her rival is $\widetilde{t}_i(t_j)$ such that $d\pi_i/dt_i = 0$. Then, the intersection of the best response functions gives the equilibrium termination fees t_A^* and t_B^*.[12] We show the existence of the following types of equilibria.

Lemma 3. *If the network effects are low ($\beta_S\beta_C < (9 - 2\beta_C^2)/6$), the termination fees are strategic substitutes and the equilibrium is stable. If the network effects are moderate ($(9 - 2\beta_C^2)/6 < \beta_S\beta_C < (27 - 4\beta_C^2)/18$), the termination fees are strategic complements and the equilibrium is unstable. If the network effects are relatively high ($(27 - 4\beta_C^2)/18 < \beta_S\beta_C < (9 - \beta_C^2)/6$), the termination fees are strategic complements and the equilibrium is stable. If the network effects are high ($(9 - \beta_C^2)/6 < \beta_S\beta_C$), then the second order conditions $d^2\pi_A/dt_A^2 < 0$ and $d^2\pi_B/dt_B^2 < 0$ are not satisfied.*

Proof. See Appendix A. □

The different types of equilibria are summarized in Figure 2. The fact that the termination fees can be either strategic complement or substitutes is explained by the opposite effects of an increase in the termination fee set by ISP j on the gain or loss incurred by ISP i if she raises her termination fee. From (19) and (20),

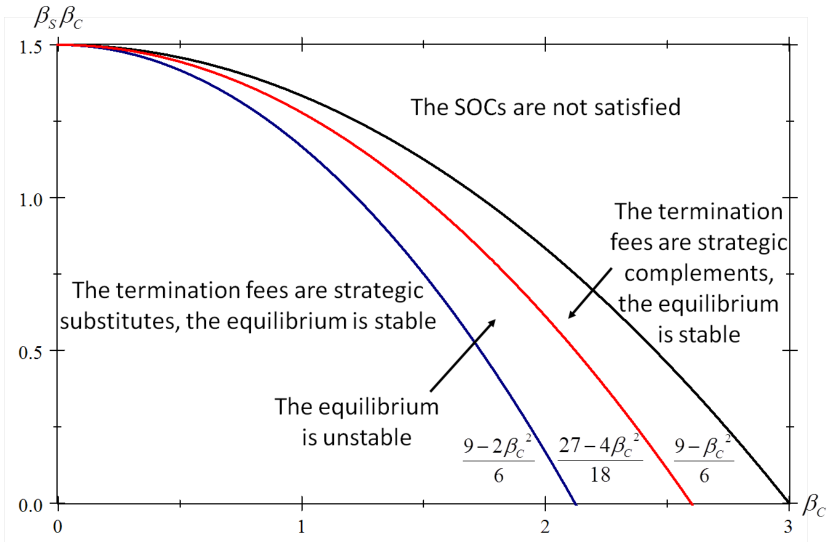
$$\frac{d^2\pi_i}{dt_i dt_j} = \underbrace{\frac{\partial \widetilde{q}_i}{\partial t_j}\frac{\partial \widetilde{p}}{\partial t_i} + \frac{\partial \widetilde{p}}{\partial t_j}\frac{\partial \widetilde{q}_i}{\partial t_i}}_{=d\triangle_R^i/dt_j>0} + \underbrace{\frac{\partial \widetilde{n}}{\partial t_j}}_{=d\triangle_T^i/dt_j<0}, \quad i, j \in \{A, B\}, \ i \neq j. \tag{21}$$

On the one hand, an increase in the termination fee set by j reduces the loss in retail profit incurred by i when she raises t_i (from Table 1, $d \triangle_R^i /dt_j > 0$). This is because when t_j is higher, $\tilde{q}_i$ and $\tilde{p}$ are also lower, and therefore, the loss for ISP i from a higher termination fee is lower. On the other hand, a higher t_j reduces entry from CPs, which reduces the gains for ISP i from raising her termination fee (from Table 1, $d\triangle_T^i/dt_j < 0$). We find that the latter effect dominates if the network

[12] Due to their algebric complexity, we omit the expressions of t_A^* and t_B^* here (see Appendix A).

effects are of low magnitude ($\beta_S\beta_C < (9-2\beta_C^2)/6$). Then, there is a negative relation between the termination fee that maximizes ISP i's profit and the termination fee set by ISP j (the termination fees are strategic substitutes). Otherwise, the former effect dominates and there is a positive relation between the termination fee that maximizes ISP i's profit and the termination fee set by ISP j (the termination fees are strategic complements).

Figure 2: The different types of equilibria



5.2 Access regulation and the unregulated termination fees

The trade-off faced by ISP A when she sets her termination fee is affected by the access price. Indeed, from (19),

$$\frac{d^2\pi_A(\widetilde{q_A},\widetilde{q_B},\widetilde{n})}{dadt_A} = \underbrace{\frac{\partial\widetilde{q_A}}{\partial a}\frac{\partial\widetilde{p}}{\partial t_A} + \frac{\partial\widetilde{p}}{\partial a}\frac{\partial\widetilde{q_A}}{\partial t_A}}_{=d\triangle_R^A/da<0 \text{ or} >0} + \underbrace{\frac{\partial\widetilde{q_B}}{\partial t_A}}_{=d\triangle_W^A/da<0} + \underbrace{\frac{\partial\widetilde{n}}{\partial a}}_{=d\triangle_T^A/da<0}. \tag{22}$$

As shown in Section 5.1 an increase in t_A would reduce the wholesale profit of ISP A because it lessens the number of users of ISP B. Obviously, the higher is the access price, the stronger is this effect. This corresponds to the second term in (22), which is negative ($d\triangle_W^A/da < 0$). An increase in t_A would also increase the termination revenue per content, which in turn increases the termination profit. Since there is a negative relation between the access price and the number of

CPs (Lemma 2), an increase in the access price would lessen the increase in the termination profit. The corresponds to the last term in (22), which is also negative ($d \triangle_T^A /da < 0$).

Finally, the first term in (22) can be interpreted as follows. In Section 5.1 we have also shown that an increase in t_A would reduce ISP A's retail profit. The relation between the access price and the intensity of the decrease in ISP A's retail profit depends on the strength of the network effects. If the network effects are weak, then both the Internet subscription fee and the number of users of ISP A increase with the access price (Lemma 2). In this case an increase in the access price would worsen the loss incurred by ISP A. Indeed, if $\beta_C\beta_S < 1$, then $\frac{\partial \widetilde{p}}{\partial a} > 0$ and $\frac{\partial \widetilde{q_A}}{\partial a} > 0$, which implies $\frac{\partial \widetilde{q_A}}{\partial a}\frac{\partial \widetilde{p}}{\partial t_A} < 0$, $\frac{\partial \widetilde{p}}{\partial a}\frac{\partial \widetilde{q_A}}{\partial t_A} < 0$, and eventually $d \triangle_R^A /da < 0$. If the network effects are strong, then both the Internet subscription fee and the number of users of ISP A decrease with the access price. In this case, an increase in the access price would soften the loss incurred by ISP A. Indeed, if $\beta_C\beta_S \geq 1$, then $\frac{\partial \widetilde{p}}{\partial a} \leq 0$ and $\frac{\partial \widetilde{q_A}}{\partial a} \leq 0$, which implies $\frac{\partial \widetilde{q_A}}{\partial a}\frac{\partial \widetilde{p}}{\partial t_A} \leq 0$, $\frac{\partial \widetilde{p}}{\partial a}\frac{\partial \widetilde{q_A}}{\partial t_A} \leq 0$, and eventually $d \triangle_R^A /da \geq 0$.

To sum up, if the network effects are weak, an increase in the access price would lower the gain and increase the loss that would result from an increase in t_A ($d\triangle_T^A/da < 0$ and $d\triangle_R^A/da + d\triangle_W^A/da < 0$). In this case, there is a negative relation between the access price and $\widetilde{t_A}$. If the network effects are strong, an increase in the access price would lessen the gain that would result from an increase in t_A ($d \triangle_T^A /da < 0$), but it may reduce the corresponding loss ($d \triangle_R^A /da + d \triangle_W^A /da$ may be positive because $d \triangle_R^A /da$ is positive). However, we find that the former effect always dominates. Finally, there is a negative relation (waterbed effect) between the access price and the termination fee set by ISP A.

The trade-off faced by ISP B when she sets her termination fee is also affected by the access price. From (20),

$$\frac{d^2\pi_B(\widetilde{q_A}, \widetilde{q_B}, \widetilde{n})}{dadt_B} = \underbrace{\frac{\partial \widetilde{q_B}}{\partial a}\frac{\partial \widetilde{p}}{\partial t_B} + \frac{\partial \widetilde{p}}{\partial a}\frac{\partial \widetilde{q_B}}{\partial t_B}}_{=d\triangle_R^B/da>0} + \underbrace{\frac{\partial \widetilde{n}}{\partial a}}_{=d\triangle_T^B/da<0} . \tag{23}$$

On the one hand, an increase in the access price reduces the loss in retail profit that ISP B would incur if she raised her termination fee (from Lemma 2, $d \triangle_R^B /da > 0$). On the other hand it would lower the corresponding gain ($d \triangle_T^B /da < 0$). We find that the former effect dominates, and that there is a positive relation (complementarity effect) between the access price and the termination fee set by ISP B.

Finally, the relation between the access price and the termination fees can be summarized as follows.

Proposition 2. *i. For any given t_B, there is a negative relation (waterbed effect) between the access price and the termination fee set by the integrated ISP. ii. For any given t_A, there is a positive relation (complementarity effect) between the access price and the termination fee set by the non-integrated ISP. iii. If the termination fees are strategic substitutes, there is a negative relation between the access price and the termination fee set in equilibrium by ISP A , and a positive relation between the access price and the termination fee set in equilibrium by ISP B. If the termination fees are strategic complements, the relation between the access price and the equilibrium termination fees may be either positive or negative.*

Proof. See Appendix B. □

5.3 Access regulation and welfare

Since welfare decreases with both the access price and the termination fees (Proposition 1), Proposition 2 implies that raising the access price may improve welfare when the termination fees are unregulated. Indeed, raising the access price has a direct negative impact on welfare because it lowers the number of subscribers and the number of CPs (Section 4). However, it may also have an indirect positive impact on welfare: A higher access price may result in lower termination fees (Proposition 2), which would in turn improve welfare, because it would increase the number of CPs and the number of subscribers (Section 4).

Overall, we find that the direct negative impact of an increase in the access price always dominates its indirect positive effect. Nevertheless, our model indicates that the social benefits from a low access price will often be undermined by high termination fees (see Appendix C).

6 Conclusion

In this paper, we have considered a key issue in the debate on net neutrality: the impact of access price regulation on the ISPs' incentives to deviate from net neutrality. Our findings challenge the popular assumption that fostering competition through proper access regulation helps keeping the

Internet neutral. In particular, we found that there may be a negative relation between the access price and unregulated termination fees. This result is explained by the presence of two opposite effects: the complementarity effect and the waterbed effect.

We have also pointed out that the high termination fees that may arise from a low access price would be socially inefficient. To some extent, our results call for regulation of both access and net neutrality (whereas in most countries only access is regulated). However, our framework is too simple to infer that enforcing net neutrality is always desirable. In particular, we ignored dynamic issues such as the relation between net neutrality and capacity investment. As reported in the literature, these dynamic issues result in a complex relation between net neutrality and welfare. Consequently, the next stage of this research should be to propose a model including both competition between asymmetric interconnected platforms and capacity investment.

Appendix A: The equilibrium termination fees (proof of Lemma 3)

From (2), (3), (13), (14) and (15), the second order conditions $\frac{\partial^2 \pi_A}{\partial t_A^2} < 0$ and $\frac{\partial^2 \pi_B}{\partial t_B^2} < 0$ are satisfied if and only if $\beta_S \beta_C < \frac{9-\beta_C^2}{6}$. Since, by assumption $\beta_S > 0$, this condition may hold if and only if $\beta_C < 3$. In other words, the second order conditions are satisfied if and only if the network effects are not too strong. In this case, ISP i's best reply to the termination fee t_j set by her rival is $\widetilde{t_i}(t_j)$ such that $d\pi_i/dt_i = 0$. It is just a matter of computation to show that

$$\widetilde{t_A} = -\frac{2\beta_C^2 t_B - 9t_B + 6\alpha\beta_S - 2\alpha\beta_C - 3a\beta_S - 6c_r\beta_S - 3c_n\beta_S - 5a\beta_C + 2c_r\beta_C + 7c_n\beta_C}{12\beta_S\beta_C + 2\beta_C^2 - 18} - \frac{6\beta_S\beta_C t_B + 4\beta_S\beta_C^2 a + 2\beta_S^2\beta_C a + 4\beta_S^2\beta_C c_r - 4\beta_S\beta_C^2 c_n + 2\beta_S^2\beta_C c_n - 4\alpha\beta_S^2\beta_C}{12\beta_S\beta_C + 2\beta_C^2 - 18}, \tag{24}$$

$$\widetilde{t_B} = -\frac{2\beta_C^2 t_A - 9t_A + 6\alpha\beta_S - 2\alpha\beta_C - 3a\beta_S - 6c_r\beta_S - 3c_n\beta_S + 4a\beta_C + 2c_r\beta_C - 2c_n\beta_C}{12\beta_S\beta_C + 2\beta_C^2 - 18} - \frac{6\beta_S\beta_C t_A - 2\beta_S\beta_C^2 a + 2\beta_S^2\beta_C a + 4\beta_S^2\beta_C c_r + 2\beta_S\beta_C^2 c_n + 2\beta_S^2\beta_C c_n - 4\alpha\beta_S^2\beta_C}{12\beta_S\beta_C + 2\beta_C^2 - 18}. \tag{25}$$

From (24) and (25), $\frac{\partial \widetilde{t_A}}{\partial t_B} = \frac{\partial \widetilde{t_B}}{\partial t_A} = \frac{-2\beta_C^2 - 6\beta_S\beta_C + 9}{2\beta_C^2 + 12\beta_S\beta_C - 18}$. If $\beta_S\beta_C < \frac{9-2\beta_C^2}{6}$, then $\frac{\partial \widetilde{t_A}}{\partial t_B}, \frac{\partial \widetilde{t_B}}{\partial t_A} < 0$ and the termination fees are strategic substitutes. If $\beta_S\beta_C > \frac{9-2\beta_C^2}{6}$, then $\frac{\partial \widetilde{t_A}}{\partial t_B}, \frac{\partial \widetilde{t_B}}{\partial t_A} > 0$ and the termination fees are strategic complements.

The equilibrium termination fees t_A^* and t_B^* are given by the intersection of the best reply functions. From (24) and (25), we find

$$t_A^* = -\frac{6\alpha\beta_S - 2\alpha\beta_C + 2a\beta_C^3 - 2c_n\beta_C^3 - 3\beta_S c_r - 6\beta_S c_r - 3\beta_S c_n - 14a\beta_C + 2\beta_C c_r}{4\beta_C^2 + 18\beta_S\beta_C - 27} -$$

$$\frac{16\beta_C c_n + 10a\beta_C^2\beta_S + 2a\beta_C\beta_S^2 + 4\beta_C^2\beta_S c_r - 10\beta_C\beta_S^2 c_n + 2\beta_C\beta_S^2 c_n - 4\alpha\beta_C\beta_S^2}{4\beta_C^2 + 18\beta_S\beta_C - 27}, \tag{26}$$

$$t_B^* = -\frac{6\alpha\beta_S - 2\alpha\beta_C - 2a\beta_C^3 + 2c_n\beta_C^3 - 3\beta_S c_r - 6\beta_S c_r - 3\beta_S c_n + 13a\beta_C + 2\beta_C c_r}{4\beta_C^2 + 18\beta_S\beta_C - 27} -$$

$$\frac{-11\beta_C c_n - 8a\beta_C^2\beta_S + 2a\beta_C\beta_S^2 + 4\beta_C^2\beta_S c_r + 8\beta_C\beta_S^2 c_n + 2\beta_C\beta_S^2 c_n - 4\alpha\beta_C\beta_S^2}{4\beta_C^2 + 18\beta_S\beta_C - 27}. \tag{27}$$

This equilibrium is stable if and only if $\frac{\partial \widetilde{t_A}}{\partial t_B}\frac{\partial \widetilde{t_B}}{\partial t_A} < 1$. It is just a matter of computation to show that this is the case for $\beta_S\beta_C < \frac{9-2\beta_C^2}{6}$ and for $\frac{27-4\beta_C^2}{18} < \beta_S\beta_C < \frac{9-\beta_C^2}{6}$.

Appendix B: Impact of the access price on the termination fees (proof of Proposition 2)

i. The impact of the access price on the termination fee set by ISP A given the termination fee set by ISP B is $\frac{\partial \widetilde{t_A}}{\partial a} = \frac{-2\beta_S^2\beta_C - 4\beta_S\beta_C^2 + 3\beta_S + 5\beta_C}{12\beta_S\beta_C + 2\beta_C^2 - 18}$ (from (24)). It is easily seen that $\frac{\partial \widetilde{t_A}}{\partial a} < 0$ for all $\beta_S\beta_C < \frac{3}{2}$.

ii. The impact of the access price on the termination fee set by ISP B given the termination fee set by ISP A is $\frac{\partial \widetilde{t_B}}{\partial a} = \frac{2\beta_S^2\beta_C - 2\beta_S\beta_C^2 - 3\beta_S + 4\beta_C}{-2\beta_C^2 - 6\beta_S\beta_C + 9}$ (from (25)), and it is just a matter of computation to show that $\frac{\partial \widetilde{t_B}}{\partial a} > 0$ for all $\beta_C < 3$.

iii. The impact of a variation in the access price on the equilibrium termination fees is given by $\begin{cases} \frac{dt_A^*}{da} = \frac{\partial \widetilde{t_A}}{\partial a} + \frac{\partial \widetilde{t_A}}{\partial t_B}\frac{dt_B^*}{da} \\ \frac{dt_B^*}{da} = \frac{\partial \widetilde{t_B}}{\partial a} + \frac{\partial \widetilde{t_B}}{\partial t_A}\frac{dt_A^*}{da} \end{cases}$. From this system we find $\frac{dt_A^*}{da} = \frac{\frac{\partial \widetilde{t_A}}{\partial a} + \frac{\partial \widetilde{t_A}}{\partial t_B}\frac{\partial \widetilde{t_B}}{\partial a}}{1 - \frac{\partial \widetilde{t_A}}{\partial t_B}\frac{\partial \widetilde{t_B}}{\partial t_A}}$ and $\frac{dt_B^*}{da} = \frac{\frac{\partial \widetilde{t_B}}{\partial a} + \frac{\partial \widetilde{t_B}}{\partial t_A}\frac{\partial \widetilde{t_A}}{\partial a}}{1 - \frac{\partial \widetilde{t_A}}{\partial t_B}\frac{\partial \widetilde{t_B}}{\partial t_A}}$. Since we assumed that the equilibrium is stable, $1 - \frac{\partial \widetilde{t_A}}{\partial t_B}\frac{\partial \widetilde{t_B}}{\partial t_A} > 0$. As shown above, $\frac{\partial \widetilde{t_A}}{\partial a} < 0$ and $\frac{\partial \widetilde{t_B}}{\partial a} > 0$. If the termination fees are strategic substitutes (i.e. if $\frac{\partial \widetilde{t_B}}{\partial t_A} = \frac{\partial \widetilde{t_A}}{\partial t_B} < 0$), then $\frac{\partial \widetilde{t_A}}{\partial a} + \frac{\partial \widetilde{t_A}}{\partial t_B}\frac{\partial \widetilde{t_B}}{\partial a} > 0$ and $\frac{\partial \widetilde{t_B}}{\partial a} + \frac{\partial \widetilde{t_B}}{\partial t_A}\frac{\partial \widetilde{t_A}}{\partial a} < 0$, which implies $\frac{dt_A^*}{da} < 0$ and $\frac{dt_B^*}{da} > 0$. If the termination fees are strategic complements (i.e. if $\frac{\partial \widetilde{t_B}}{\partial t_A} = \frac{\partial \widetilde{t_A}}{\partial t_B} > 0$), then $\frac{\partial \widetilde{t_A}}{\partial a} + \frac{\partial \widetilde{t_A}}{\partial t_B}\frac{\partial \widetilde{t_B}}{\partial a}$ and $\frac{\partial \widetilde{t_B}}{\partial a} + \frac{\partial \widetilde{t_B}}{\partial t_A}\frac{\partial \widetilde{t_A}}{\partial a}$ may be either positive or negative.

Appendix C: Impact of the access price on welfare

Since the CPs multihome, it makes sense to define the total termination fee t as the sum of the termination fees charged by both ISPs ($t = t_A + t_B$). Welfare can be written as a function of this total termination fee. Indeed, from (11), (12) and (15), $W = \widetilde{q_C}(t).\widetilde{q_S}(t)\beta_S - \frac{\widetilde{q_C}(t)^2}{2} + \widetilde{p}(t).\widetilde{q_S}(t) + \frac{\widetilde{q_S}(t)^2}{2}$ where $\widetilde{q_C} = \frac{2\alpha\beta_S - 3t - \beta_S(a+2c_r+c_n)}{3-2\beta_S\beta_C}$, $\widetilde{q_S} = \frac{2\alpha - 2\beta_C t - a - 2c_r - c_n}{3-2\beta_S\beta_C}$, and $\widetilde{p} = \frac{\alpha + a(1-\beta_S\beta_C) - \beta_C t + c_n(1-\beta_S\beta_C) + 2c_r(1-\beta_S\beta_C)}{3-2\beta_S\beta_C}$.

Proposition 1 implies that welfare decreases with the total termination fee, and that there may be a positive relation between the access price and welfare if raising the access price lowers the unregulated total termination fee. Formally, $\frac{dW(t^*)}{da} = \frac{\partial W(t)}{\partial a} + \left.\frac{\partial W(t)}{\partial t}\right|_{t=t^*} \frac{\partial t^*}{\partial a}$ where $t^* = t_A^* + t_B^*$; Since $\frac{\partial W(t)}{\partial a} < 0$ and $\frac{\partial W(t)}{\partial t} < 0$, $\frac{\partial t^*}{\partial a} < 0$ is a necessary condition for $\frac{dW(t^*)}{da} > 0$. From (26) and (27), $\frac{\partial t^*}{\partial a} = \frac{-4\beta_S^2\beta_C - 2\beta_S\beta_C^2 + 6\beta_S + \beta_C}{4\beta_C^2 + 18\beta_C\beta_S - 27}$, and it is just a matter of computation to show that $\frac{\partial t^*}{\partial a} < 0$ if $\beta_S\beta_C < \frac{9-2\beta_C^2}{6}$ and if $\beta_S\beta_C > \frac{\sqrt{\beta_C^4 - 2\beta_C^2 + 9} - \beta_C^2 + 3}{4}$.

Although, the condition $\frac{\partial t^*}{\partial a} < 0$ is satisfied for a wide range of values of β_S and β_C (see e.g. Figure 2), it is just a matter of computation to show that an increase in the access price always reduces welfare when the termination fees are non-negative.

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