Net Neutrality in a hyperlinked Internet economy*

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March 7, 2018

Abstract

In this paper, we study the welfare implications of the zero-price rule of the Net Neutrality (NN) regulation in an economy where two competing Content Providers (CPs) can engage in interlinking agreements. When CPs link their contents, they attract indirect visitors who first visit one CP and then the other so as to benefit from the complementarities of their products. We show that CPs are interested in reaching a linking agreement when the termination fee set by the Internet Service Provider (ISP) is not particularly high. The ISP may also find it profitable to set a low termination fee that leads CPs to reach a linking agreement. First, it benefits from the increase in the Internet traffic, provided that its cost of transmitting content is not too high. And second, the links increase the consumers' willingness to pay for the service, which allows it to set a higher subscription fee. Last, we show the cases in which the regulation of the termination fee can increase social wefare. We also point out that when the ISP's transmission cost is sufficiently low the imposition of the NN principle is justifiable, although this is a sufficient, but not a necessary, condition for welfare maximization.

*The authors are grateful for valuable feedback received from two anonymous referees. Joan Calzada acknowledges financial support from the Spanish Ministry of Economy and Competitiveness (ECO2015-69193R).

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1 Introduction

Nowadays, an important percentage of the visits received by Content Providers (CPs) in the Internet is originated in other web sites. For instance, direct visits to The Washington Post and The New York Times represent only 25% and 44%, respectively, of their total traffic, whereas the rest of traffic is originated in social platforms and search engines, or is referral from other news sites such as blogs. Similarly, direct visits to social platforms like Facebook and Twitter represent 61% and 55%, respectively, of their incoming visits.[1] Hence, a key feature of the Internet economy is that CPs place virtually costless links to third-party content so as to complement their own product.

Although there is available software to block or undermine the use of links, most sites usually allow and promote them. The reason is that the indirect traffic generated by the links constitutes an important source of visits and advertisement revenues.[2] In this sense, for example, many online newspapers maintain formal agreements with other content providers, such as msn.com, in order to exchange traffic. In the same vein, most social platforms offer the option of promoting the users' websites on other social networks, and allow users to share their contents with their social media contacts.

The extended use of links seems to have crucially been encouraged by the Net Neutrality (NN) principle that governs the Internet. This implies that Internet Service Providers (ISPs) must equally treat the information packets sent by CPs and must not charge them any fee. Bourreau & Lestage (2013) explain that the NN principle implies that:

(i) The ISPs are not allowed to charge CPs an additional fee for terminating their content to end users ("no-pricing rule"); and

(ii) The ISPs are mandated to offer all CPs the same quality of service, and thus they cannot prioritize certain types of traffic ("no-discrimination and no-prioritization rule").

In the last years, scholars and policy makers have intensively discussed the welfare consequences of imposing the NN principle, focusing on its effect on innovation and competition.[3] Yet, an aspect that has received very little attention is the effect of this regulation on the use of hyperlinks by CPs. The objective of this paper is to analyze the impact of a deviation from the zero-price rule on the linking strategy of CPs and to examine its effect on welfare maximization.

We consider a model in which two competing CPs decide whether to stay independent or to reach a linking agreement. Without links, users only consume the content of one CP, whereas links allow them to access the contents of the

[1] Information retrieved from Similarweb, a web measurement company.

[2] Marshall (2007) and Flavián & Gurrea (2009) explain that readers may visit different news sites to follow a breaking story or to search specific details about the story. Saez-Trumper et al. (2013) show that visits to different sites may be used to obtain alternatives approaches to the same story or to verify it. Lehmann et al. (2016) find that providing links to external content increases engagement and re-engagement.

[3] See Brennan (2017), Greenstein et al. (2016) and Katz (2017) for a review of the recent developments of the regulation on NN in the United States and the European Union. For a review of the economic literature on this topic, see also Schuett (2010) and Faulhaber (2011).

two CPs. As a consequence, links can be viewed as a mechanism to increase the quality of the service and to attract indirect visitors. CPs obtain advertising revenues from the traffic they receive and pay a per-unit termination fee to a monopolist ISP for the network capacity used. The ISP, in turn, sets a fixed subscription fee to Internet users and a termination fee to CPs in order to maximize its overall profit.

Our first finding is that CPs have an incentive to reach a linking agreement provided that the termination fee set by the ISP is not too high. This implies that NN is sufficient, but not necessary, condition to incentivize interlinking agreements between CPs. In particular, a less restrictive regulation which consists in setting an upper bound for the termination fee would be sufficient to induce the linking agreement. The reason is that CPs find it profitable to lower the advertisement time included in their contents in order to attract indirect users, as long as the termination fee is not particularly high. The profitability of the links also depends on the level of complementarity of the contents of the two CPs.

Second, we identify a trade-off faced by the ISP when setting the termination fee: on the one hand, a high termination fee allows the extraction of more surplus from CPs; on the other hand, a sufficiently low termination fee induces the use of links and increases the consumer surplus that can be extracted via the subscription fee. The optimal strategy of the ISP hinges upon its cost of transmitting the contents: if this cost is sufficiently low, the ISP sets a low termination fee that allows for interlinking agreements; and if it is sufficiently high it sets a high termination fee that disincentivizes them.

The main policy implication of the paper is derived by comparing the profit-maximizing and the welfare-maximizing termination fees. We show that when the ISP's transmission cost is sufficiently low or sufficiently high, no regulatory intervention is needed because the unregulated termination fee maximizes social welfare. In particular, when the transmission cost is sufficiently low, the privately optimal termination fee incentivizes the linking agreement; and when it is high, it blocks the agreement. Interestingly enough, in these two cases the regulation of the termination fee just redistributes rents between the consumers and the ISP.

On the other hand, the regulation of the termination fee may be required for some intermediate values of the transmission cost, for which the ISP mainly finds it profitable to set a high termination fee, but social welfare is maximized with a lower termination fee that increases the number of users who use the links. The reason is that the ISP does not fully internalize the impact of the links on the consumers. We explain that, in this context, the imposition of the NN policy is sufficient, but not necessary, provision to reach social optimality.

We last discuss whether some of the assumptions considered in the model can affect our results. First, we examine the case in which the subscription fee charged to the end users is capped, which can reflect the regulation of the telecommunications market. In this case, the ISP cannot directly extract the additional utility that the users obtain with the links, and thus it sets a higher termination fee that makes the linking agreement less likely. Second, we analyze the case where CPs endogenously choose the quality of their contents. We show that the quality offered by CPs decreases with the termination fee, and that they invest less in quality when they reach a linking agreement. In this situation, the ISP uses the termination fee to influence the quality offered by the CPs and the traffic they generate.

The rest of the paper is organized as follows. Section 2 reviews the related literature. Section 3 describes the main characteristics of the model. Section 4 presents the solution of the game when the ISP can freely set the termination fee and when this fee is regulated. The comparison of these cases allows us to examine the welfare implications of the NN rule. Section 5 presents some extensions of the model. Finally, Section 6 concludes. The proofs of all results are given in the Appendix.

2 Literature Review

The economic implications of the Net Neutrality regulation are of great interest, given the relevance of the telecommunication sector for the overall performance of the economy (Katz et al., 2010; Czernich et al., 2011). In the last years, there has been an intensive policy debate about the effectiveness of Net Neutrality (NN) to promote welfare, content creation, and the deployment of next generation telecommunications networks. In this direction, several academic papers have analyzed the effects of deviating from this rule. According to Krämer et al. (2013), the Non-Net Neutrality (NNN) scenarios can be categorized into the "network regime" and "the pricing regime". The former regime corresponds to a managed network in which the ISPs may employ Quality of Service (QoS) mechanisms to degrade or block contents which are harmful to the ISPs, as well as offer preferential treatment to the information packets of some CPs (e.g., priority arrangements). The latter regime refers to the case in which the ISPs can engage in two-sided pricing schemes and charge both end users and CPs. It is thus convenient to separately review these two strands of the literature.

Congestion on the ISP's network results in delays in the delivering of quality sensitive traffic. This means that giving a preferential treatment to this type of traffic could generate better efficiency outcomes both from a static and a dynamic perspective. The research articles analyzing the network regime have considered the effects of NN on the incentives of the ISPs to expand the capacity of their infrastructures (Cheng et al., 2011; Krämer & Wiewiorra, 2012), on the incentives of CPs to innovate (Guo & Easley, 2016), and on the investment incentives of both ISPs and CPs (Bourreau et al., 2015; Choi & Kim, 2010; Reggiani & Valletti, 2016). Another group of papers have examined the impact of a deviation from the NN rule on social welfare (Choi et al., 2015; Economides & Hermalin, 2012; Peitz & Schuett, 2016; Guo et al., 2017;). Overall, different approaches adopted to define congestion and model firms' strategic choices yield different results about the effectiveness of a managed network to encourage investments and increase social welfare.

There is also a growing stream of the literature studying the welfare implications of deviating from the zero-price rule. Economides & Tåg (2012) analyze the impact of termination fees on the pricing strategy of a monopolist ISP and show that implementing network neutrality regulations can be either beneficial or harmful for the society depending on the degree of the network effects for consumers and content providers. Njoroge et al. (2014) and Bourreau & Lestage (2017) challenge the social optimality of the zero-price rule when two ISPs compete for attracting end users and content providers. Njoroge et al. (2014) find that a non-neutral regime increases the investment levels chosen by the ISPs and decreases CP participation; but since the first effect dominates, social welfare is larger when positive termination fees are allowed. Bourreau & Lestage (2017) consider a vertically-integrated ISP that provides the non-integrated ISP with access to its last-mile network at a per-unit access price. They find that the termination fee set by the integrated ISP increases with the access price, whereas the social optimum calls for the net neutrality rule and cost-based access regulation.

The above articles assume that CPs are local monopolies, and hence they do not account for the consequences of the deviation from the zero-price rule on the competition in the content market. Kourandi et al. (2015) and D'Annunzio & Russo (2015) address this question by explicitly considering two competing CPs and modelling the impact of the zero-price rule on the emergence of exclusive contracts between ISPs and CPs (i.e., Internet fragmentation). Their main difference is that Kourandi et al. (2015) treats the termination fee as an exogenous factor, whereas D'Annunzio & Russo (2015) studies the strategic use of the termination fees to induce fragmentation. The two papers conclude that the zero-price rule is not always sufficient to prevent fragmentation.[4]

The main contribution of our paper to this literature is the study of the welfare implications of deviating from the zero-price rule when CPs can engage in interlinking agreements. Although hyperlinks are an essential element of the Internet market, this aspect has been overlooked in the current debate about NN. In a similar way as D'Annunzio & Russo (2015) and Kourandi et al. (2015), we explicitly consider competition between two CPs, but instead of studying the impact of the termination fees on Internet fragmentation we analyze how the ISP can strategically use the termination fee to affect the interlinking agreements.

From this perspective, our paper can also be related to another recent literature that has analyzed strategic linking in the Internet market. Katona and Sarvary (2008) were the first to analyze competition between web sites in a market for advertising links. Mayzlin and Yoganarasimhan (2012) show that links can be used by bloggers to signal the quality of their contents to consumers. Dellarocas et al. (2013) examine competition between news sites that obtain revenue from user visits and that link the contents of their rivals.

In a related paper, Anderson et al. (2017) consider competition between CPs when end users can either visit only one CP, or first visit one CP and then another, where in the latter case they may incur a disutility from the overlapping

[4]As Broos & Gautier (2017) show, the same outcome can be derived in a setting where ISPs may find it profitable to exclude competing one-way essential complements (i.e., Internet applications competing with their own products).

contents. Our model closely follows this setup, considering that consumers can single-visit or multiple-visit CPs, depending on their preferences, the attributes of the contents and the strategic choices of firms. However, we introduce two important changes. First, in order to represent the Internet market, we consider that CPs can reach linking agreements that allow them to complement their contents. As a consequence, consumers click to the links to access contents that are not offered by the first visited CP or to access different versions of the same content. Thus, visiting several CPs does not necessarily imply either an overlap in consumption or multiple payments for the same content. Second, we introduce an ISP that strategically sets the termination fee to influence the CPs linking choice. This extension allows us to examine the effects of the NN rule.

In this context, we identify an interesting trade-off faced by the ISP when setting the prices in the two sides of a fully covered broadband market. In particular, we show that when the ISP's transmission cost is sufficiently low, it reduces the level of the termination fee in order to induce CPs to reach linking agreements. This strategy increases total traffic and end users' surplus, which can be extracted through a higher subscription fee. The relationship between the termination and the subscription fees resembles the "waterbed effect" identified by the literature on Net Neutrality in settings where market participation is endogenously derived (Bourreau & Lestage, 2017; Economides & Tåg, 2012; Greenstein et al., 2016). In the context of these papers, however, the ISPs react to the imposition of the NN regulation by increasing the subscription fee, because attracting more end users becomes less profitable.

3 Model description

Consider a market with two Content Providers, CP_i with $i = \{1, 2\}$, which can be accessed through the network of an Internet Service Provider (ISP). Following the model of Anderson et al. (2017), we consider that CPs offer a content that is characterized by its attributes. We denote the universe of possible attributes that any CP can deliver by φ and define $Q_i \subseteq \varphi$ the set of attributes that CP_i offers. We assume that all attributes have the same intrinsic valuation for consumers and we normalize the universe of possible attributes to 1. Let Q_i be drawn randomly from φ, and $q_i \in [0, 1]$ denote the measure of Q_i. Therefore, an increase in q_i translates into a better quality content that makes CP_i more attractive to consumers. For example, if CP_i was an online newspapers, then q_i would represent its information coverage. Indeed, online newspapers do not cover all the events of the day or do not offer complete information about each event. If the CP was a social platform, the attributes could be a set of services, such as on line communications, the management of private videos and images, or the provision of breaking news. We consider that the creation of content is costly and CPs cannot offer the complete universe of attributes to consumers.

In addition to their vertical differentiation aspect, the contents of CPs are also horizontally differentiated. The two CPs compete à la Hotelling and each of them is located at one extreme of a unit line [0,1], with CP_1 located at the far left (point 0) and CP_2 at the far right (point 1). We further assume that consumers are uniformly distributed along this line, as well as that the valuation they place to the content of CPs is increasing in the set of attributes these offer.

The model of Anderson et al. (2017) introduces an important modification to the Hotelling model, which is that the set of attributes offered by CPs interacts with the distance-based utility. Thus, when a consumer located at $x \in [0, 1]$ visits only CP_i, she obtains an utility $(R - tx)q_i$, where R is the intrinsic valuation generated by the content, and tx is the disutility from imperfect preference matching, which increases with the "distance" of the consumer from CP_i. This approach implies that the smaller the imperfect preference matching, the higher the valuation of each additional attribute.

The interaction between horizontal and vertical differentiation well reflects the Internet market, in which an increase in the number of attributes of a content is not perceived in the same way by all consumers. In particular, the inclusion of an additional attribute by a CP will be more valued by those consumers who are located closer to that CP. To illustrate this situation, imagine a digital newspaper that increases its coverage for a particular event. According to this assumption, the new information will be more valuable for the regular readers of the newspaper than for the readers of other newspapers. Similarly, the inclusion of Twitter or Facebook in Youtube channels will be more appreciated by Youtubers rather than for the frequent users of other video-sharing websites.[5]

On the other hand, the consumption of each content attribute implies a disutility a_i, which represents the advertisement time embedded into the content that cannot be avoided by the consumer (alternatively, a_i could reflect a direct payment to the CP). In our formulation, the advertisement time, a_i, also interacts with the sets of attributes, q_i. This implies that more attributes make consumers spend more time in the web site of CPs and see more advertisements. Finally, the consumer also pays a subscription fee, P, to the ISP for accessing the Internet.

Taking into account this description of the market, we next present the utility of consumers when CPs do not reach a linking agreement. In this case, all consumers Single-Visit (SV), which means that they only visit one CP.[6] The net utility that the consumer located at x gains from visiting only CP_1, or only

[5] The interaction between vertical and horizontal differentiation typically benefits the "loyal" consumers of the firm that increases its quality. For example, adding a color screen to Kindle's e-reader is perceived to be more valuable for a Kindle lover than for an iPad lover (Anderson et al., 2017). Note that this positive relationship does not necessarily mean that "loyal" consumers are located closer to their favorite firm. In the banking industry, for instance, depositors located far away from their favorite bank branch place a higher valuation for the possibility of managing financial transactions remotely (Degryse, 1996).

[6] We consider that in the absence of links consumers only visit one CP. This assumption can be seen as realistic since consumer search for complementary contents in other websites can be very costly, and because visiting all CPs can entail unwanted overlaps.

CP_2, is the following:

$$
\begin{aligned}
U_1 &= (R - tx)q_1 - a_1 q_1 - P; \\
U_2 &= (R - t(1-x))q_2 - a_2 q_2 - P.
\end{aligned} \tag{1}
$$

Content providers compete for consumers, but they can also link each other to enhance their contents. For example, digital newspapers set links to each other to complement their coverage on an event. Similarly, Twitter and Facebook are linked to give users a better communication experience. We consider that CPs can reach a linking agreement that allows them to offer some of the content of their rivals. Otherwise, they block the use of their contents by the other CP.

When CPs reach a linking agreement, consumers are allowed to Multi-Visit (MV), which means that after visiting the web site of a CP, they can click to the links that lead to the content of the other CP. The additional utility that consumers can get through the links depends on the degree of complementarity between the CPs' attributes. Following Anderson et al. (2017), we interpret $q_i q_j$ as a measure of the overlap of the attributes of CP_i and CP_j and $(1-q_i)q_j$ as a measure of the attributes that are different in the two CPs with $\{i, j\} = \{1, 2\}$ and $i \neq j$. Taking this into account, we consider that the incremental valuation provided by the links is $(1-q_i)q_j + \beta q_i q_j = q_j V_i$, where β reflects the time that consumers spend on duplicated attributes (alternatively, β can be interpreted as the proportion of duplicated contents that are linked). If $\beta = 0$ consumers do not obtain any utility from consuming duplicated attributes, whereas if $\beta > 0$ they obtain an additional value from consuming the same attribute twice. We assume that $\beta \in [0, 1)$ to ensure that an increase in q_i does not lead to an increase in the incremental utility provided by the links.

The utility of the consumer that Multi-Visits (MV) depends on the order of their visits. The net utility of a consumer located at x when she first visits CP_1 and then CP_2, or vice versa, is given respectively by:

$$
\begin{aligned}
U_{12} &= U_1 + (R - t(1-x))q_2 V_1 - a_2 q_2 V_1; \\
U_{21} &= U_2 + (R - tx)q_1 V_2 - a_1 q_1 V_2.
\end{aligned} \tag{2}
$$

According to this formulation, the attributes of the other CP that are linked generate a disutility to the consumers due to imperfect preference matching. As as a result, the utility of consumers depend on their location in the unit line. Also notice that CPs are interested in linking the contents of their rivals in order to complement their own service. If they do not set links, they can still receive indirect traffic from their rival, but they become less attractive from the consumer's perspective.

The profit of each CP depends on whether they have reached a linking agreement. Consider first that they do not reach an agreement, and thus all consumers SV. Defining D_i as the aggregate demand for CP_i, we can write its profit as:

$$\pi_i^S = D_i(a_i - f)q_i \tag{3}$$

where "S" stands for "*Single-Visit*". In this profit function, it has been assumed that for each unit of advertisement time sold, the CP obtains a price, which is normalized to 1. On the other hand, f is the per-unit termination fee that each CP pays to the ISP for using its telecommunications network. This fee may be set by the ISP or it might be regulated. We assume that the network capacity that CPs buy from the ISP depends on the provided set of attributes. If they offer more attributes (e.g., more news stories, pictures and videos covering an event), they generate more traffic per user that requires to contract more capacity from the ISP. Thus, the total payment that CPs make to the ISP depends on the termination fee, the number of visitors and the number of attributes they offer.

With the linking agreement, CP_i gets revenues from its direct and indirect visitors:

$$\pi_i^M = D_i(a_i - f)q_i + D_{ji}(a_i - f)q_iV_j, \tag{4}$$

where "M" stands for "*Multi-Visits*". In this expression, D_i is the mass of consumers that directly visit CP_i, whereas D_{ji} is the number of consumers that first visit CP_j and then click through to the links to visit CP_i. Notice that the advertisement time per attribute, a_i, is the same for direct and indirect visitors. On the other hand, the existence of links makes CPs to contract more capacity from the ISP as they have to deliver their contents to both direct and indirect visitors.

The ISP's revenue comes from the retail market through the subscription fee charged to all consumers and from the wholesale market through the termination fee. In particular, its profit is:

$$\pi_{ISP} = P + fQ - \mu Q^2, \tag{5}$$

where $Q = q_iD_i + q_jD_j$ when all consumers choose to SV and $Q = q_iD_i + q_jD_j + q_iD_{ji}V_j + q_jD_{ij}V_i$ when at least some consumers choose to MV. Note that the Internet traffic generates a cost to the ISP, μQ^2, where $\mu > 0$ represents the rate at which the transmission cost becomes marginally more expensive. Taking this into account, in the next section we analyze how the ISP sets the termination fee in order to optimize the transmitted traffic. Moreover, given the two-sided nature of the ISP, we examine the relationship between the termination and the subscription fees. In what follows, we consider that the subscription fee, P, is freely chosen by the ISP, provided that it results in full consumer participation. This assumption is in line with the current universal service regulation established in many countries, which requires the affordability of the broadband access.[7]

[7] Notice also that the broadband market is highly mature and its difussion process is approaching its saturation level. In 2016, 74% of EU homes had a fixed broadband subscription, whereas 99% of OECD inhabitants had access to mobile broadband. This suggest that changes in the firms' pricing strategies are unlikely to attract a large number of new consumers to the market. See "Broadband market developments in the EU 2017" at https://ec.europa.eu/digital-single-market/en/european-digital-progress-report and "OECD

4 Analysis

The objective of this section is to examine the welfare implications of the termination fee that CPs pay to the ISP for gaining access to its network. We compare the privately and socially optimal termination fees to determine the conditions under which the regulation of the market can increase social welfare.

We consider the following timing of the game. In the first stage, the ISP sets the subscription fee, whereas the termination fee is either set by the ISP at its profit-maximizing level or by the regulator at its welfare-maximizing level. In the second stage, the two CPs make their linking decisions, implying that they choose whether they reach an agreement to share their contents or not. In the third and final stage, CPs decide the advertisement time that they include in their contents and users make their decisions with respect to content consumption. We solve the model by backward induction.

4.1 Stage 3: Retail competition

In the third stage of the game, the termination and the subscription fees have been set and the two CPs have chosen their linking strategy. Taking this into account, CPs determine the advertisement time embedded into their contents. In order to derive the equilibrium of this stage, we analyze competition between CPs when there are not links, meaning that all consumers Single-Visit (SV), and when there are links, meaning that consumers have the opportunity to Multi-Visit (MV).

Single-Visit. By equating U_1 and U_2 in (1) and solving for x we obtain that the consumer who is indifferent between buying from CP_1 and CP_2 is located at $\hat{x} = \frac{R(q_1-q_2)+tq_2-a_1q_1+a_2q_2}{(q_1+q_2)t}$. Taking this into account, we can write the demand of each CP as $D_1 = \hat{x}$ and $D_2 = (1-\hat{x})$, respectively. Based on this information, CPs set the advertisement time that maximizes the profit function given in (3). The first order condition of the profit with respect to a_i gives the advertisement time that maximizes the profit of CP_i, with $i \neq j$:

$$\begin{aligned} a_i^S &= \frac{1}{3q_i}[R(q_i-q_j)+f(2q_i+q_j)+t(q_i+2q_j)] \\ \pi_i^S &= \frac{[(R-f)(q_i-q_j)+t(q_i+2q_j)]^2}{9\,(q_i+q_j)\,t} \end{aligned} \tag{6}$$

Assuming symmetric CPs ($q_i = q$) the indifferent consumer, the advertisement time and the profit obtained by each CP are:

$$\hat{x} = \frac{1}{2};\ a_i^S = f+t;\quad \text{and } \pi_i^S = \frac{qt}{2}. \tag{7}$$

This result shows that when all consumers SV the termination fee is completely passed through to consumers via the advertisement time. As a result,

broadband statistics update" at http://www.oecd.org/sti/broadband/broadband-statistics-update.htm

CPs equilibrium profit does not depend on f. On the other hand, from (1) we obtain that to ensure full participation we need $U(x=1/2)\geq 0$, which requires $f\leq \overline{f}=R-\frac{3t}{2}-\frac{P}{q}$. Specifically, $\overline{f}$ is the termination fee that leads the consumer located at $\hat{x}$ to be indifferent between contracting the Internet service or staying outside the market. With a higher termination fee this consumer would not buy at all.

Multi-Visits. When CPs reach an agreement and set links, consumers can either choose to visit just one CP, or first visit one CP and then click to the links that lead to the other. CPs can induce consumers to SV or to MV by suitably adjusting the advertisement time. Solving $U_1 = U_{12}$ for x, we obtain that the consumer who first visits CP_1 and then is indifferent between visiting CP_2 or not is $\hat{x}_1 = (a_2 - R + t)/t$. Similarly, solving $U_2 = U_{21}$ for x shows that the consumer who first visits CP_2 and then is indifferent between visiting CP_1 or not is $\hat{x}_3 = (R - a_1)/t$. Finally, solving $U_{12} = U_{21}$ for x gives the consumer who visits both CPs but who is indifferent about which one to visit first: $\hat{x}_2 = (t - a_1 + a_2)/2t$. Note that the consumers who are more likely to SV are those located closer to the extremes of the unit line because they incur a higher disutility when they click the links and visit the CP located at the other extreme of the unit line.

The objective of each CP is to set the advertisement time that maximizes its profit given in (4) when taking into account that $D_1 = \hat{x}_2$, $D_2 = (1-\hat{x}_2)$, $D_{12} = (\hat{x}_2 - \hat{x}_1)$ and $D_{21} = (\hat{x}_3 - \hat{x}_2)$. The first order condition of Eq. (4) with respect to a_i gives the advertisement time that maximizes the profit of CP_i with $i, j = 1, 2$ and $i \neq j$:

$$\begin{aligned} a_i &= \frac{t(3+V_i)(1-V_j) + f(1+V_i)(3+V_j) + 2R(V_i + V_j(2+V_i))}{5(V_i+V_j) + 3(1+V_iV_j)}; \\ \pi_i &= \frac{q_i(1+V_j)(t(3+V_i)(V_j-1) + 2(f-R)(V_i+(2+V_i)V_j))^2}{2t\,(5(V_j+V_i)) + 3(1+V_iV_j))^2}. \end{aligned} \quad (8)$$

With symmetric CPs, the solution of this problem yields:

$$\begin{aligned} \hat{x}_1 &= (1-\hat{x}_3) = \frac{(f-R+2t)(1+V)}{(1+3V)\,t};\ \text{and}\ \ \hat{x}_2 = \frac{1}{2}; \\ a_i^M &= \frac{f+t+(2R+f-t)V}{1+3V}; \\ \pi_i^M &= \frac{q(1+V)(t+(2(R-f)-t)V)^2}{2t\,(1+3V)^2}; \end{aligned} \quad (9)$$

These results imply that CPs share the market equally and that f determines the number of consumers that SV. Notice that an increase in the termination fee raises the advertisement time and reduces the number of consumers that MV (increases $\hat{x}_1$ and reduces $\hat{x}_3$). Unlike the SV case, CPs do not fully incorporate the termination cost into the advertisement time in order to attract indirect visitors. On the other hand, the profit in (9) negatively depends on the termination fee.

The optimal level of a_i in (9) ensures an interior solution where at least some consumers SV ($\hat{x}_1 > 0$ and $\hat{x}_3 < 1$) if $f > R-2t$, and where at least some consumers MV ($\hat{x}_1 < \hat{x}_2$ and $\hat{x}_3 > \hat{x}_2$) if $f < R - \frac{t(3+V)}{2(1+V)}$. Therefore, an interior solution exist for $f \in [R-2t, R-\frac{t(3+V)}{2(1+V)}]$. The fact that $R - \frac{t(3+V)}{2(1+V)} \geq \overline{f}$ means that $0 < \hat{x}_1 < \hat{x}_2 < \hat{x}_3 < 1$ for every value of f in the interval $(R-2t, \overline{f}]$.

When $f \leq R-2t$, the advertisement times are so low that all consumers MV. Taking this into account, the CPs' problem is now to choose a_i so as to maximize the profit in (5) when $\hat{x}_1 = 0$ and $\hat{x}_3 = 1$. Assuming symmetric firms, the optimal advertisement time and the associated profit are given by:

$$\begin{aligned} a_i^{ML} &= f + \frac{t(1+V)}{1-V}; \\ \pi_i^{ML} &= \frac{qt(1+V)^2}{2(1-V)}. \end{aligned} \tag{10}$$

where "ML" stands for "*Low*" values of the termination fee under "*Multi-Visits*". Notice, however, that when $R - \frac{2t}{1-V} < f \leq R-2t$ the advertisement time a_i^{ML} is so high that some consumers SV (i.e., $\hat{x}_1 > 0$ and $\hat{x}_3 < 1$). In this case, the maximum advertisement time which ensures that all consumers MV is $a_i^{MM} = R - t$. Therefore:

$$\begin{aligned} a_i^{MM} &= R-t; \\ \pi_i^{MM} &= \frac{q(R-f-t)(1+V)}{2}. \end{aligned} \tag{11}$$

where "MM" stands for "Medium" values of the termination fee under the "*Multi-Visits*" case. In contrast to the previous results, a_i^{MM} is negatively related to t, meaning that when the degree of horizontal differentiation increases, CPs should reduce the advertisement time to attract all the consumers who initially visit their rival. Otherwise some consumers SV.[8] Finally, notice that $a_i^{ML} \leq a_i^{MM} \leq a_i^{M}$, which implies that the advertisement time needs to be smaller (consumers get less disutility) when $f \leq R-2t$ and all consumers MV.

4.2 Stage 2: Linking decision

In the second stage of the game each CP decides whether to reach a linking agreement with its rival or not. This decision is based on the comparison of the profit they obtain under SV and MV. The following proposition summarizes the CPs' optimal linking strategy.

[8] When $a_i^{MM} = R-t$, the two CPs are interested in deviating by setting a lower advertisement time when $R - \frac{2t}{1-V} < f$, which is precisely the case in which the CPs set a_i^{ML}.

Proposition 1: *Let* $\hat{f} = R - \frac{t((V^2-1)+(1+3V)\sqrt{1+V})}{2V(1+V)}$ *denote the termination fee that makes CPs indifferent between SV and MV, and* $\tilde{q}$ *denote the set of content attributes for which* $\hat{f} = \overline{f}$*. Then, the CPs linking strategy is as follows:*

(i) When $q \leq \widetilde{q}$*, CPs always reach a linking agreement since* $\hat{f} \geq \overline{f}$*. All consumers MV for* $f \in (0, R-2t]$*, whereas only some consumers MV for* $f \in (R-2t, \overline{f})$*.*

(ii) When $q > \widetilde{q}$*, CPs reach a linking agreement if* $f < \widehat{f}$ *, with* $\widehat{f} \in (R-2t, \overline{f})$*. All consumers MV if* $f \in [0, R-2t]$ *and only some consumers MV if* $f \in (R-2t, \widehat{f})$*. For* $f \in (\widehat{f}, \overline{f}]$*, CPs don't reach an agreement and all consumers SV.*

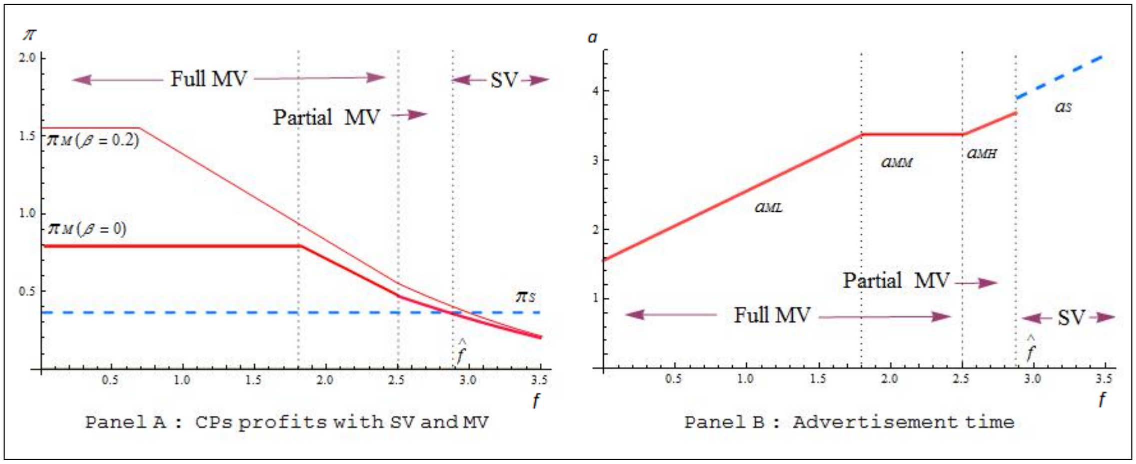

Figure 1: **Linking decision**. This figure illustrates the second part of Proposition 1. The continuous red lines represent the equilibrium outcomes under MV and the dashed blue lines the results under SV. When $f > \widehat{f}$, it is satisfied that $\pi_i^S > \pi_i^M$ and there is no linking agreement. Parameters $R = 4.5$, $t = 1$ and $q = 0.75$. With SV we consider $P = 0$. In Panel B we consider $\beta = 0$.

Part (i) of Proposition 1 shows that when q is sufficiently small, CPs always find it profitable to link their contents. In fact, links allow CPs to complement the limited set of attributes they offer. In order to attract indirect visitors from their competitor, they reduce the advertisement time embedded in each content attribute, but the advertisement revenue they obtain with this policy is higher than by blocking the links.

Part (ii) shows that when $q > \widetilde{q}$, CPs are interested in reaching a linking agreement provided that the termination fee f is not too high (see Panel A in Figure 1). On the one hand, they obtain additional revenues by attracting indirect visitors through a low advertisement time. On the other hand, getting more consumers increases their overall termination costs. When the termination fee is sufficiently high (i.e., $f > \widehat{f}$), the latter effect dominates, and CPs prefer to block the links to induce all consumers to SV. If there is not an agreement, they insert more advertisement time into their contents since they don't have to attract indirect visitors from the other CP (see Panel B in Figure 1).

Finally, notice that the linking agreement is more likely when there is complementarity between the contents offered by CPs, which implies a positive relationship between β and $\widehat{f}$. The continuous lines in Panel A of Figure 1 show the profit of CPs with MV when $\beta = 0$ and when $\beta = 0.2$, whereas the dashed line shows their profit with SV. Clearly, when the complementarity between the contents of the two CPs increases, π_i^M increases, thus leading the threshold value $\widehat{f}$ to increase.

The main policy implication of Proposition 1 with respect to the NN rule is shown in the following statement:

Corollary 1: *The linking agreement is always reached when $f \in [0, \widehat{f})$. Net Neutrality is thus sufficient, but not necessary, condition for inducing the linking agreement.*

More generally, the proposition offers insights about the incentives of content providers to reach linking agreements in the Internet market. The links allow CPs to offer more utility to their direct consumers and to attract indirect consumers that generate additional revenue. However, such agreements are profitable as long as the termination cost is not too high.

4.3 Stage 1: Optimal termination fees

4.3.1 An unregulated ISP

Consider next that in the first stage of the game an *unregulated* ISP sets the termination fee, taking into account its effect on the CPs' linking decision. Before analyzing the ISP's optimal termination strategy, we present its profit under SV and MV.

Lemma 1: *The profit of an unregulated ISP is as follows:*

(i) If it prefers consumers to SV, it sets $f^S > \widehat{f}$ and obtains $\pi_{ISP}^S = (R - \frac{3t}{2})q - \mu q^2$. This strategy can be implemented for $q \in (0.36, 1]$.

(ii) If it prefers consumers to MV, the termination fee it sets depends on the transmission cost: when $\mu \in (0, \mu_1)$, it sets $f^{ML} = R - 2t$ and obtains $\pi_{ISP}^{ML} = \frac{q(1+V)(2R-3t)-2\mu(q(1+V))^2}{2}$; when $\mu \in (\mu_1, \mu_2)$, it sets f^{MM} and obtains $\pi_{ISP}^{MM} = \frac{q(1+V)(2Rt-3t^2+R^2V+2\mu qt(1+V))}{2(t(1+3V)+2\mu qV(1+V))}$; and when $\mu > \mu_2$, it sets $f^{MH} = \widehat{f}$ and obtains $\pi_{ISP}^{MH} = \frac{q((\sqrt{1+V}-1-2V)t+V(R\sqrt{1+V}-\mu q(1+V))}{V}$, where μ_1 and μ_2 are functions of q given in the Appendix.

The profit of the ISP with SV does not depend on f because there is a complete pass through of the termination fee from the CPs to the consumers through the advertisement time (see Eq. (7)). As a result, the ISP uses the termination and the subscription fees to extract the consumers' surplus, provided that full consumer participation is ensured. In spite of this, it must set $f^S > \widehat{f}$ to induce SV. Notice also that π_{ISP}^S is increasing in q as long as μ is not too large since an increase in the number of attributes increases the traffic, but also the ISP's transmission cost.

With MV, the termination fee determines the indirect traffic from one CP to the other, thus affecting the ISP's termination revenue and its transmission cost. When the cost of transmitting traffic is small ($\mu < \mu_1$), it sets $f^{ML} = R - 2t$, which is the largest level that leads all consumers to MV. When the cost is higher ($\mu_1 < \mu < \mu_2$), it increases the termination fee, inducing CPs to increase their advertisement time and some consumers to SV. Finally, when the cost is even higher ($\mu > \mu_2$), it sets $f^{MH} = \widehat{f}$, which is the maximum termination fee that maintains the interest of CPs for the linking agreement. Indeed, with a larger fee the CPs don't reach an agreement.

Finally, we compare the ISP's profit under SV and MV so as to determine its optimal strategy.

Proposition 2. *The ISP's optimal termination policy is as follows:*

(i) When $\mu < \widehat{\mu} = \frac{2RV\left(\sqrt{1+V}-1\right)+t\left(2\sqrt{1+V}-2-V\right)}{2qV^2}$, the ISP sets a low termination fee $f < \hat{f}$ which leads CPs to reach a linking agreement: if $\mu \in (0, \mu_1)$, it sets f^{ML} and all consumers MV; i*f* $\mu \in (\mu_1, \mu_2)$, *it sets* f^{MM} *and only some consumers MV*; and if $\mu \in (\mu_2, \widehat{\mu})$, it sets $f^{MH} = \hat{f}$ and only some consumers MV.

(ii) When $\mu > \widehat{\mu}$, the ISP sets $f^S > \hat{f}$ which leads CPs to avoid a linking agreement.

Proposition 2 shows that when $\mu < \widehat{\mu}$ the ISP chooses a termination fee that leads CPs to reach a linking agreement (i.e., $f < \hat{f}$). The links benefit the ISP for two reasons. First, it obtains more Internet traffic, which increases its profit as long as the increase in its termination revenue outweighs the increase in its transmission cost. And second, the links generate an additional utility to consumers which can be extracted by the ISP through the subscription fee. Specifically, the links make consumers more homogeneous because those that are located closer to the middle of the Hotelling line are the ones who find less costly to visit a second CP. As a consequence, the ISP is able to increase the subscription fee for all consumers.

The second part of Proposition 2 shows that when $\mu > \widehat{\mu}$, the additional traffic generated by the links does not compensate the increase in the ISP's capacity cost. As a consequence, the ISP sets a termination fee that leads CPs to discard the linking agreement, i.e., $f^S > \hat{f}$. It is interesting to point out that the threshold $\widehat{\mu}$ depends negatively on the degree of complementarity β. This is because a higher β increases the indirect traffic generated by the links which increases the ISP's capacity costs and makes the agreement less profitable for

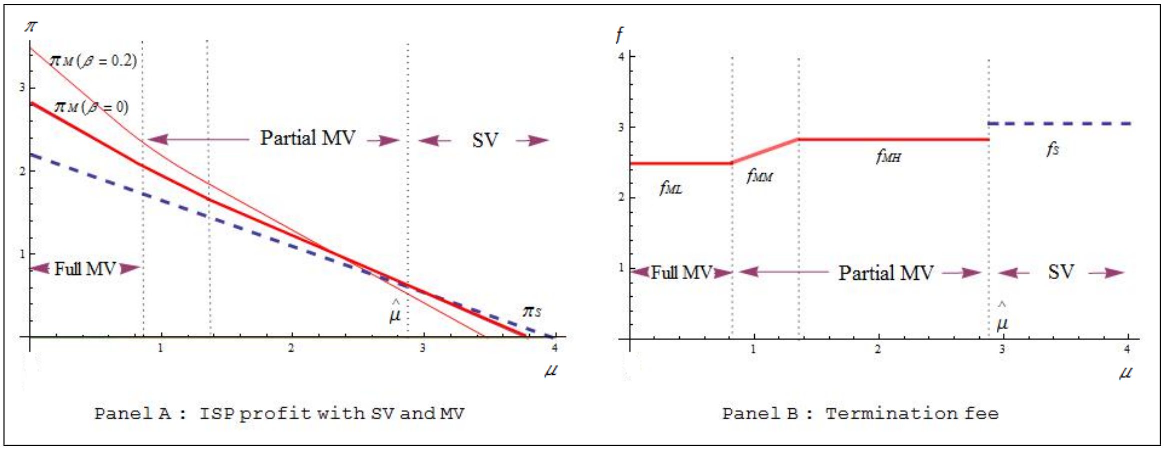

Figure 2: **ISP's optimal termination policy**. This figures illustrates Proposition 2. The continuous red lines represent the equilibrium outcomes under MV and the dashed blue lines the results under SV. When $\mu > \widehat{\mu}$, it is satisfied that $\pi_{ISP}^{S} > \pi_{ISP}^{M}$ and the ISP does not induce the linking agreement. Parameters $R = 4.5$, $t = 1$ and $q = 0.75$. With SV we consider $P = 0$. In panel B we consider $\beta = 0$.

him. Panel A in Figure 2 presents the profit of the ISP with MV when $\beta = 0$ and $\beta = 0.2$, showing that the larger is the degree of complementarity, the smaller is the threshold value for $\widehat{\mu}$.

To sum up, our results show that the ISP can set a low termination fee to incentivize CPs to reach a linking agreement. The links increase the Internet traffic, which increases the ISP's profit as long as the transmission cost is low. When the transmission cost is sufficiently high, the ISP sets a termination fee that blocks the linking agreement between the CPs.

4.3.2 A sector-specific regulator

The previous section studied the privately optimal termination fee charged by the ISP in an unregulated market. However, nowadays most countries have adopted the Net Neutrality (NN) rule, which implies a zero termination fee (i.e., $f = 0$). Taking this into account, we next analyze the welfare-maximizing termination pricing in an hyperlinked Internet market, and we discuss the necessity for the NN regulation. For this objective, we define Social Welfare (SW) as the unweighted sum of consumers surplus (CS) and industry profits: $SW = CS + \pi_1 + \pi_2 + \pi_{ISP}$.

Next we present the derived SW when consumers SV and when MV in a context where the regulator sets the termination fee and the ISP sets the subscription fee.

Lemma 2: *When CPs are symmetric and the termination fee is regulated, social welfare is as follows:*

(i) If society is better off when consumers SV, the regulator sets $f_R^S > \widehat{f}$ *and social welfare is* $SW^S = q(R - \frac{t}{4}) - \mu q^2$.

(ii) If society is better off when consumers MV, the welfare-maximizing termination fee set by the regulator depends on the ISP's transmission cost:

when $\mu < \overline{\mu}_1$, *the regulator sets* $f_R^{ML} \leq R-2t$ *and social welfare is* $SW^{ML} = \frac{q(4R(1+V)-t(1+3V)-4\mu q(1+V)^2)}{4}$;

when $\overline{\mu}_1 < \mu < \overline{\mu}_2$, he sets $f_R^{MM} = \frac{(2\mu q(1+V)-t)(t(1-V)+2RV)}{(1+V)(t+4\mu qV)}$ and *the society obtains* $SW^{MM} = \frac{q(V(4\mu qt+(t-2R)^2)-t(4(\mu q-R)+t))}{4(4\mu qV+t)}$; *and*

when $\mu > \overline{\mu}_2$, *he sets* $f_R^{MH} = \hat{f}$ *which yields* $SW^{MH} = \frac{(2R-t)(V+\sqrt{1+V}))}{2\left(1+\sqrt{1+V}\right)} + \frac{q(2R-2\mu q(1+V)(1+\sqrt{1+V})}{2\left(1+\sqrt{1+V}\right)}$; *where* $\overline{\mu}_1$ *and* $\overline{\mu}_2$ *are functions of* q *given in the Appendix.*

The economic intuition of this lemma is similar to that of Lemma 1. Social welfare with SV is independent of f since the ISP adjustes the subscription fee to the regulated termination fee to ensure consumers' full participation. Indeed, in this case an increase in the termination fee reduces CS by the same amount that increases the ISP's profit. With MV, the termination fee determines the indirect traffic from one CP to the other. Like the privately optimal termination fee, the welfare-maximizing one depends on the ISP's transmission cost. When the cost is low ($\mu < \overline{\mu}_1$), the regulator sets a low fee (f_R^{ML}) which induces all consumers to MV. For higher values of the capacity cost ($\overline{\mu}_1 < \mu < \overline{\mu}_2$), he increases the termination fee (f_R^{MM}), which in turn increases the CPs' advertisement time and reduces the number of consumers that MV. Finally, with a higher transmission cost ($\mu > \overline{\mu}_2$), the regulator is forced to limit the value of the termination fee (f_R^{MH}) to avoid inducing CPs to block the links.

Finally, the following proposition compares the social welfare levels under SV and MV in order to determine the optimal termination policy.

Proposition 3. *The welfare-maximizing termination policy is as follows:*

(i) When $\mu < \hat{\mu}_R = \frac{t(1-\sqrt{1+V})+2V(2R-t)}{4qV(1+\sqrt{1+V})}$, *the regulator sets* $f < \hat{f}$, *and CPs reach a linking agreement: if* $\mu < \overline{\mu}_1$, *he sets* $f_R^{ML} \leq R-2t$ *and all consumers MV; if* $\mu \in (\overline{\mu}_1, \overline{\mu}_2)$, *he sets* f_R^{MM} *and thus only some consumers MV; and if* $\mu \in (\overline{\mu}_2, \hat{\mu}_R)$, *he sets* f_R^{MH} *and only some consumers MV.*

(ii) When $\mu > \hat{\mu}_R$, *the regulator sets* $f_R^S > \widehat{f}$ to induce all consumers to SV.

The proposition shows that the socially optimal termination policy follows a similar pattern as the privately optimal one. In particular, when the transmission cost is higher than $\hat{\mu}_R$, the use of links is so costly for the society that the regulator sets $f > \widehat{f}$ to induce all consumers to SV. By contrast, for lower values of the transmission cost, the regulator reduces the termination fee so as to induce CPs to reach a linking agreement.

Finally, we analyze the conditions under which the regulatory intervention is necessary for implementing the socially optimal outcome.

Corollary 2. *The regulation of the termination fee is only necessary for $\mu \in [\mu_1, \overline{\mu}_2]$ and $[\widehat{\mu}_R, \widehat{\mu}]$. The imposition of the Net Neutrality principle could be justified only when $\mu \in [\mu_1, \overline{\mu}_1]$, even though it represents a sufficient, but not a necessary, condition for increasing social welfare.*

Putting together the results of Propositions 2 and 3, we deduce that when μ is sufficiently low, both the unregulated ISP and the welfare-maximizing regulator set $f \leq R - 2t$ which leads all consumers to MV. Specifically, in a regulated market the regulator sets $f \leq R - 2t$ when $\mu < \overline{\mu}_1$, whereas the unregulated ISP sets $f = R - 2t$ when $\mu < \mu_1$. Given that $\mu_1 < \overline{\mu}_1$, we conclude that the two scenarios generate the same level of social welfare for $\mu < \mu_1$. However, the regulation of the termination fee is needed when $\mu_1 \leq \mu \leq \overline{\mu}_1$ because an unregulated ISP would set a higher termination fee. This situation is illustrated in Figure 3.

On the other hand, when μ is sufficiently high, the privately and the socially optimal termination policies generate the same welfare level because $f > \widehat{f}$, and thus all consumers SV. Notice that the regulator sets $f > \widehat{f}$ when $\mu > \widehat{\mu}_R$ and an unregulated ISP for $\mu > \widehat{\mu}$. Since $\widehat{\mu}_R < \widehat{\mu}$, we conclude that the two cases generate the same social welfare level for $\mu > \widehat{\mu}$. Therefore, the regulation of the termination fee is needed when $\widehat{\mu}_R \leq \mu \leq \widehat{\mu}$ because $f_R^S > f^{MH}$. In this interval of the transmission cost the regulator prefers to block the links because they generate a reduction in the consumer surplus that is not internalized by the ISP. Indeed, the links allow the unregulated ISP to increase the subscription fee.

For intermediate values of the transmission cost ($\overline{\mu}_1 < \mu < \hat{\mu}_R$) we obtain the following results: the unregulated ISP sets f^{MM} if $\mu \in [\overline{\mu}_1, \mu_2)$ and $f^{MH} = \widehat{f}$ if $\mu \in (\mu_2, \hat{\mu}_R]$, whereas the regulator sets f_R^{MM} if $\mu \in (\overline{\mu}_1, \overline{\mu}_2)$ and $f^{MH} = \widehat{f}$ if $\mu \in (\overline{\mu}_2, \hat{\mu}_R)$. Given that $\mu_2 < \overline{\mu}_2$, we conclude that the regulation of the termination fee is only required for $[\overline{\mu}_1, \overline{\mu}_2]$.

In summary, the maximization of social welfare requires the regulation of the termination fee when μ belongs to the intervals $[\mu_1, \overline{\mu}_2]$ and $[\widehat{\mu}_R, \widehat{\mu}]$. In the other cases, the private and social incentives with respect to the termination fee are aligned. Also notice that when $\mu \in [0, \overline{\mu}_1]$, the imposition of the Net Neutrality principle ($f = 0$) leads to the maximization of social welfare, but similar results could be obtained with a less restrictive regulation that imposes $f \leq R - 2t$. In fact, for this level of the transmission costs the regulation of the termination fee only affects the distribution of the rents between the ISP and the two CPs. Finally, it is interesting to highlight that the socially optimal termination fee is strictly positive for $\mu > \overline{\mu}_1$. In this case, the adoption of the

Net Neutrality rule will be detrimental for social welfare because it induces all consumers to MV which inefficiently increases the Internet traffic.

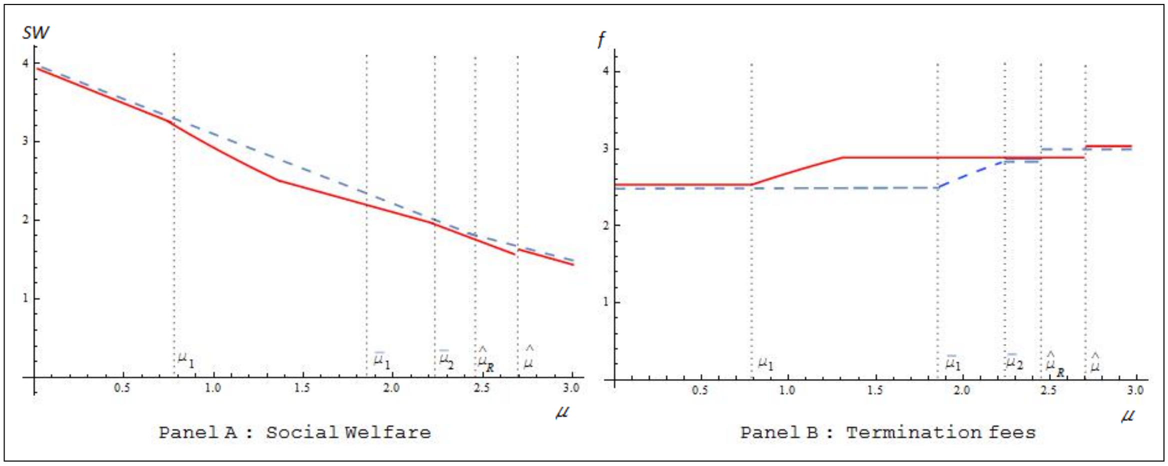

Figure 3: **Equilibrium results with and without the regulation of the termination fee.** The dashed blue lines show the case with the socially optimal termination fee and the continous red lines the case with the privately optimal fee. Parameters $R = 4.5$, $t = 1$ and $q = 0.75$. With SV we consider $P = 0$.

5 Discussion

Our previous analysis showed that an unregulated ISP may strategically reduce the termination fee in order to induce CPs to reach a linking agreement. We next argue that this incentive could be affected by its ability to define the subscription fee. Moreover, we discuss how the termination fee affects the linking agreements when the CPs endogenously choose the number of attributes they offer.

5.1 The role of the subscription fee

Proposition 2 showed that when the ISP's transmission cost is sufficiently low, the ISP chooses a low termination fee to induce CPs to reach a linking agreement. The reason is that the links increase the Internet traffic and they generate an increase in the utility of consumers that can be extracted with the subscription fee. It is important to point out, however, that this effect depends on the ability of the ISP to exert its market power in the retail market. If the subscription fee was capped, for example due to a strict regulation, then the ISP would set a higher termination fee in the MV case, and hence CPs would be less likely to reach the linking agreement.

Proposition 4. *When the subscription fee is capped and lower than the profit-maximizing one, the ISP sets a higher termination fee which blocks the linking agreement for lower values than* $\widehat{\mu}$.

This result highlights the important relationship between the subscription and the termination fees in two-sided markets. The relevance of this relationship has already been highlighted in the literature on Net Neutrality (see, for instance, Shiff 2008; and Greenstein et al., 2016), which explains the presence of a "waterbed effect" whereby telecommunications operators can raise the subscription fee if they are imposed to establish a zero termination fee.[9] In models in which consumers' participation in the market is endogenously determined, the imposition of the zero-price rule leads to an increase in the subscription fee, because the ISP is not interested in attracting new consumers that generate no termination revenue. In our model, a different situation emerges since a reduction of the termination fee may induce the establishment of a linking agreement, which allows the ISP to set a higher subscription fee. In this context, Proposition 4 shows that the interest of the ISP to induce a linking agreement depends on its ability to modify the subscription fee. Thus, for example, when the subscription fee is capped, the ISP is less interested in reducing the termination fee to make the linking agreement more attractive for the CPs.

5.2 Endogenous number of attributes

In the previous section we have considered that the quality and the number of attributes offered by CPs is an exogenous factor. However, in some cases CPs may be able to choose the attributes of their contents. For example, MSN has gradually included a variety of services to its web portal, such as Outlook.com, Messenger and Bing that compete with other content providers. On the other hand, digital newspapers can decide the number of news stories and videos they dedicate to a particular event. To consider this case, we imagine a game with the following timing. First, the ISP sets the termination and the subscription fees. Second, the two CPs decide whether to reach a linking agreement. Third, the CPs determine the number of attributes of their contents. And finally, CPs establish the advertisement time.

To increase the number of attributes, CPs must incur a cost $\frac{kq_i^2}{2}$, where k is the rate at which increasing the number of attributes becomes marginally more expensive. For simplicity, we assume that $k \leq t$. The following result shows that CPs choose a different number of attributes when they deny and when they reach a linking agreement.

Lemma 3. *CPs choose* $q = 1$ *for low values of* f *and* k*, and they reduce the number of attributes as these costs increase. The number of attributes is larger with SV than with MV.*

[9] The "waterbed effect" can be defined as the effect whereby regulation of one price of a "multiproduct" firm causes one or more of its unregulated prices to change as a result of the firm's profit-maximizing behavior (Schiff, 2008).

Content providers invest less in new attributes when the termination fee increases because, in this case, offerring a better quality content is not so profitable. They also invest less when they reach a linking agreement because, in this situation, they can complement their contents with those of the other CP, and thus they compensate the lower quality content by obtaining indirect visitors through the links.

We next derive the CPs' linking strategy by comparing their profit under SV and MV.

Proposition 5: *The CPs reach a linking agreement for* $f \in (R-t-2k, \widehat{f}_e)$.

The intuition of this proposition is that CPs reach an agreement if the cost of creating new attributes is not too low (i.e., $f > R-t-2k$) and the termination fee is not too high (i.e., $f < \widehat{f}_e$). Panel A in Figure 4 shows the combinations of values for f and k that make CPs reach an agreement. The two conditions are represented with a plain line, and they cross each other for $k = t/2$. When $k > t/2$, CPs reach an agreement if the termination fee is in the interval $f \in (R-t-2k, \widehat{f}_e)$, which increases with k. If CPs reach an agreement, they set $q < 1$ to save costs, but the links allow them to attract indirect visitors. On the other hand, if $f > \widehat{f}_e$ the termination fee is so high that CPs don't find it profitable to use links to attract indirect visitors. As a consequence, they just offer their contents, increase q, and include more advertisement time in their contents.

Finally, we study how the ISP chooses the termination fee in the first stage of the game, taking into account its impact on the CPs linking decision and in the number of attributes they commercialize. In the Appendix we derive the profit functions of the ISP when it induces SV and MV, and in Panel B of Figure 4 we show a numerical representation of the results. We obtain that the ISP induces CPs to MV for low values of μ, and that the termination fee increases with μ (see the continuous line). When $\mu \leq \mu_{1e}$, it sets $f_e^{ML} = R - 2t$. As a consequence, CPs reach a linking agreement and all consumers MV. For larger values of μ the termination fee increases and only some consumers MV: when $\mu \in (\mu_{1e}, \mu_{2e})$ it sets f_e^{MM}, and when $\mu \in (\mu_{2e}, \widehat{\mu}_e)$ it restricts the termination fee to $f_e^{MH} = \widehat{f}_e$ so as to make CPs indifferent between SV and MV. The increase in the termination fee reduces the number of attributes created by the CPs. Finally, for $\mu > \widehat{\mu}_e$ the ISP sets $f_e^{SH} > \widehat{f}_e$ to block the linking agreements and reduce the Internet traffic (see the dashed line).

To sum up, when the number of attributes offered by CPs is set endogenously, the ISP sets a termination fee that induces CPs to reach a linking agreement when the transmission cost is low, and to stay separate when this cost is sufficiently high. This represents a similar pattern to that found in Proposition 2, where the number of attributes is exogenous.

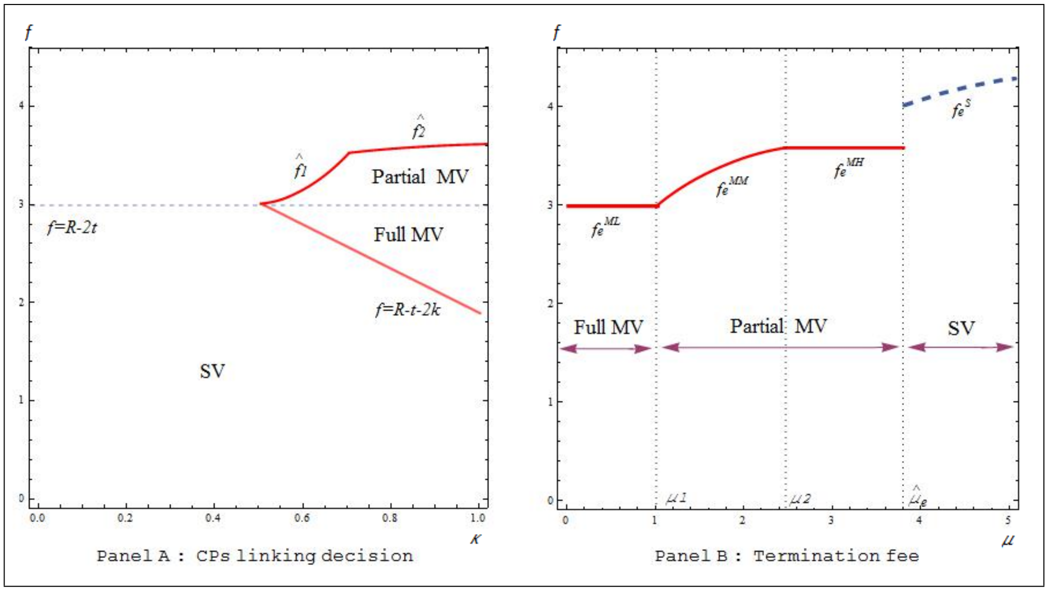

Figure 4: **Endogenous number of attributes**. Panel A shows the constellation of parameters for which CPs choose MV. Panel B shows the equilibrium termination fee set by the ISP. Parameters $R = 5$, $t = 1$ and $k = 0.75$.

6 Conclusions

In this paper, we have studied the welfare implications of the Net Neutrality (NN) regulation in an economy where Content Providers (CPs) can link to each other's content. Our model considers a fully covered market where two CPs compete for end users and can be accessed through the network of an Internet Service Provider (ISP). The ISP charges a termination fee to the CPs for using its network and a subscription fee to the end users for accessing the Internet service.

We have found that CPs have an incentive to reach a linking agreement when the termination fee set by the ISP is not too high. The reason is that they find it profitable to lower the advertisement time included in their contents in order to attract indirect users as long as the termination cost is not particularly high. The main implication is that the NN policy is a sufficient, but not necessary, condition to incentivize interlinking agreements between CPs.

Our findings also reveal that the ISP can strategically use the termination fee to promote or to disincentivize the linking agreements, and hence to influence the Internet traffic. This is an aspect that has been overlooked in the economic literature on NN, although it can have important consequences in the structure and organization of the Internet market. Specifically, we have shown that the ISP sets a low termination fee that incentivizes the interlinking agreements between the CPs when its transmission cost is sufficiently low. On the contrary, for higher transmission cost levels, the ISP increases the termination fee in order to block the use of links. This pricing policy is favored by the two-sided nature of the Internet market. Indeed, a low termination fee induces CPs to link their contents, which increases the surplus that can be extracted from the end users via the subscription fee. In this way, a monopolist ISP can compensate the lower termination fee with a higher subscription fee, provided that the increase of Internet traffic is not too costly.

An inverse relationship between the termination and the subscription fees (the so-called "waterbed-effect") has already been identified by the NN literature in models where the consumer participation in the market is endogenously determined. In these models, the imposition of the zero-price rule leads the ISP to increase the subscription fee, which reduces the participation of consumers.[10] Our model shows that a different trade-off generating the same results can emerge in a fully covered hyperlinked Internet market. Specifically, a low termination fee leads CPs to link their contents and allows the ISP to increase the subscription fee to extract the additional surplus obtained by consumers.

Finally, this paper has identified the conditions under which the regulation of the termination fee can improve social welfare. In our model, the privately and the socially optimal termination fees result in the same welfare level when: (i) the transmission cost is so low that leads to such a low optimal termination fee that induces all consumers to use the links; and (ii) the transmission cost is so high that leads to such a high optimal termination fee that blocks the links. Only when the transmission cost takes intermediate values, the welfare-maximizing and the profit-maximizing termination fees may not be aligned and the regulation of the termination fee may be necessary. In this situation, the adoption of the Net Neutrality rule can be justifiable in some specific cases, although it still represents a sufficient, but not a necessary, condition for increasing social welfare.

There are several aspects of the Internet market which have not been considered in this paper but that it would be interesting to address in future research. First, the presence of competing ISPs is frequent in the Internet market and raises new questions that should be further examined. For example, competition for attracting CPs may lead ISPs to reduce their termination fees, but it can also favor the fragmentation of the Internet market. Kourandi et al. (2015) have shown that in these cases, the application of a zero-price rule is neither a sufficient nor a necessary policy instrument to prevent fragmentation, whereas it can even be detrimental for social welfare. Taking this into account, future research could examine the welfare implications of the NN rule on Internet fragmentation in the presence of hyperlinks.

Second, the establishment of different termination fees for different content providers is an aspect that could be applied in practice. The characteristics

[10] As Greenstein et al. (2016) point out, "*given the opportunity to charge CPs for termination, the ISP is more willing to decrease the subscription fee to end users, precisely because more end users can be attracted to join the platform, resulting in more transactions with CPs that are profitable for the ISP too*".

of the contents offered by CPs would play a crucial role in such case. For instance, quality sensitive contents may call for a costly priority lane. In this context, referral traffic could be priced higher than direct traffic, or could be considered as non-prioritized. Similarly, ISPs could be interested in setting different termination fees for referral traffic originated in different CPs.

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7 Appendix

Proof of Proposition 1. When $f \in [0, R-2t]$, CPs decide whether to reach a linking agreement by comparing their profit when all consumers SV and when all consumers MV. When $f \in [0, R-\frac{2t}{1-V}]$ the comparison of the profit functions in Eqs. (7) and (10) shows that $\pi^{ML} > \pi^{S}$, and when $f \in (R-\frac{2t}{1-V}, R-2t]$ the comparison of the profit functions in Eqs. (7) and (11) shows that $\pi^{MM} > \pi^{S}$.

On the other hand, when $f \in (R-2t, \overline{f}]$ the comparison of the profits in Eqs. (7) and (9) shows that $\pi^{MH} > \pi^{S}$ when $f < \widehat{f} = R - \frac{t((V^2-1)+(1+3V)\sqrt{1+V})}{2V(1+V)}$. Since $\widehat{f} > (R-2t)$, we deduce that in the interval $f \in (R-2t, \widehat{f}]$ CPs reach an agreement that leads some consumers to MV and the rest to SV.

Finally, let $\tilde{q}$ denote the level of q which makes $\hat{f} = \bar{f}$. When $q \leq \tilde{q}$, we obtain that $\hat{f} \geq \bar{f}$, which means that CPs always prefer the linking agreement. When $q > \tilde{q}$, we observe that $\hat{f} < \bar{f}$, which implies that CPs reach an agreement for $f < \hat{f}$ and do not reach it for $f \in [\hat{f}, \bar{f}]$.

Proof of Lemma 1:

Single-Visit: Imagine that the ISP sets a termination fee that induces CPs to block the links ($f > \hat{f}$). With symmetric CPs, the ISP's profit in (5) simplifies to $\pi^{S}_{ISP} = P + fq - \mu q^2$. This expression is increasing in f, but the maximum fee that the ISP can set to ensure full consumer participation is $f^S = \overline{f} = R - \frac{3t}{2} - \frac{P}{q}$. Substituting this fee in the profit yields:

$$\pi^{S}_{ISP} = (R - \frac{3t}{2})q - \mu q^2. \tag{12}$$

Notice that f^S induces CPs to block the links when $f^S > \widehat{f}$, which occurs if

$P < \frac{\left(2q\sqrt{2-q}-3\sqrt{2-q}-3q+4\right)qt}{2(1-q)\left(\sqrt{2-q}\right)}$. Since P can not take negative values, we conclude that SV can only be implemented when $q \in (0.36, 1]$.

Multi-Visits. Consider that CPs reach a linking agreement ($f \leq \hat{f}$). When $0 \leq f \leq R - \frac{2t}{1-V}$ all consumers MV. In this case, the ISP's profit in (5) can be written as $\pi_{ISP}^{M} = P + Qf - \mu Q^2 = P + q(1+V)f - \mu\left(q(1+V)\right)^2$. Taking into account that the ISP must guarantee that all consumers participate in the market (i.e., $U(x = 1/2) \geq 0$), from (2) and the advertisement time in (10) we obtain that the subscription fee must be $P = \frac{q(1+V)((2f(V-1)-2R(V-1)-t(3+V))}{2(1-V)}$. Substituting this fee in the profit we obtain the following expression, which does not depend on f:

$$\pi_{ISP}^{M} = \frac{q(1+V)((3+V)t - 2R(1-V))}{2(V-1)} - \mu\left(q(1+V)\right)^2. \tag{13}$$

Imagine now that $R - \frac{2t}{1-V} \leq f \leq R - 2t$, which still implies that all consumers MV. As before, the ISP's profit is $\pi_{ISP}^{ML} = P + q(1+V)f - \mu\left(q(1+V)\right)^2$. From (2) and the advertisement time in (11) we obtain that full consumer participation requires $P = \frac{qt(1+V)}{2}$. Substituting this fee in π_{ISP}^{ML} we get that the profit is increasing in f. Thus, the ISP sets the maximum termination fee that leads all consumers to MV, which is $f^{ML} = R - 2t$. As a result, it obtains the following profit, which is larger than π_{ISP}^{M}.

$$\pi_{ISP}^{ML} = \frac{q(1+V)(2R-3t)}{2} - \mu\left(q(1+V)\right)^2. \tag{14}$$

Finally, consider the case where the ISP sets $R - 2t < f < \hat{f}$, which implies that some consumers that are located in the central region of the unit line MV and those that are at the extremes SV. Given the indifferent consumers in (9), the ISP maximizes $\pi_{ISP}^{MM} = P + fQ - \mu Q^2$, where $Q = 2qx_2 + qV(x_3 - x_2) + qV(x_2 - x_1) = \frac{q(1+v)(t(1-V)+2(R-f)V)}{t(1+3V)}$. In this case, from (2) and the advertisement time in (9) the maximum subscription fee that ensures full consumer participation is $P = \frac{q(1+V)(2R(1+V)-2f(1+V)-t(3+V))}{2(1+3V)}$. Taking this into account, the termination fee that maximizes π_{ISP}^{MM} is:

$$f^{MM} = \frac{(R-t)\,t\,(1+3V) - 2\mu q(1+V)(t\,(V-1) - 2RV)}{2(t(1+3V) + 2\mu qV(1+V))}. \tag{15}$$

Notice that the ISP can set f^{MM} as long as $R-2t < f^{MM} < \hat{f}$, which is satisfied for $\mu_1 < \mu < \mu_2$, where $\mu_1 = \frac{R-3t}{2q(1+V)}$ and $\mu_2 = \frac{RV(1+V)+t(1+V-\sqrt{1+V}(1+3V))}{2qV(1+V)^{3/2}}$. When $\mu < \mu_1$ the ISP sets $f^{ML} = R - 2t$ and obtains π_{ISP}^{ML} . Moreover, all consumers MV. When $\mu_1 < \mu < \mu_2$ the ISP sets f^{MM} and the derived profit is:

$$\pi_{ISP}^{MM} = \frac{q(1+V)(2Rt - 3t^2 + R^2V - 2\mu qt(1+V))}{2\left(t\,(1+3V) + 2\mu qV(1+V)\right)} \tag{16}$$

Finally, when $\mu > \mu_2$ the ISP cannot set f^{MM} because this will lead CPs to block the linking agreement. As a result, it sets $f^{MH} = \hat{f}$ which is the maximum fee that induces CPs to reach a linking agreement. Thus, it obtains:

$$\pi_{ISP}^{MH} = \frac{q((\sqrt{1+V} - 1 - 2V)t + V(R\sqrt{1+V} - \mu q(1+V))}{V}. \tag{17}$$

Proof of Proposition 2.

In order to derive the ISP's optimal termination policy we compare its profit under SV and MV.

(i) When $\mu < \mu_1$, we observe that $\pi_{ISP}^{ML} > \pi_{ISP}^{S}$ if $\mu < \frac{2R-3t}{2q(2+V)}$. Given that $\frac{2R-3t}{2q(2+V)} - \mu_1 = \frac{3t+RV}{q(4+6V+2V^2)} > 0$, we deduce that $\pi_{ISP}^{ML} > \pi_{ISP}^{S}$ is always satisfied in the relevant range of μ.

(ii) When $\mu_1 < \mu < \mu_2$, it is always satisfied that $\pi_{ISP}^{MM} - \pi_{ISP}^{S} > 0$.

(iii) When $\mu > \mu_2$, we find that $\pi_{ISP}^{MH} > \pi_{ISP}^{S}$ if

$\mu < \widehat{\mu} = \frac{2RV\left(\sqrt{1+V}-1\right)+t(2\sqrt{1-V}-V-2)}{2qV^2}$. Notice that $\widehat{\mu} - \mu_2 > 0$, meaning that $\pi_{ISP}^{MH} > \pi_{ISP}^{S}$ for $\mu_2 < \mu < \widehat{\mu}$.

Proof of Lemma 2.

Single-Visit. Under SV, consumers' surplus is a follows:

$$CS^S = \int_0^{\hat{x}} ((R - tx)q - a_1 q)dx + \int_{\hat{x}}^{1} ((R - t(1-x))q - a_2 q)dx - P. \tag{18}$$

Given symmetric CPs, the profit of the firms and consumers' surplus are:

$$\pi_i^S = \frac{1}{2}qt; \quad \pi_{ISP}^S = P - \mu q^2 + fq; \quad CS^S = q(R - \frac{5}{4}t) - P - fq. \tag{19}$$

As a result, social welfare is:

$$SW^S = \left(R - \frac{t}{4}\right) q - \mu q^2. \tag{20}$$

Multi-Visits. Under MV, the expression for the consumers' surplus is much complex because some consumers MV and the others SV.

$$
\begin{aligned}
CS^{M} &= \int_{0}^{\hat{x}_1} ((R-tx)q - a_1 q)dx + \\
&+ \int_{\hat{x}_1}^{\hat{x}_2} ((R-tx)q - a_1 q + (R-t(1-x))qV - a_2 qV dx \\
&+ \int_{\hat{x}_2}^{\hat{x}_3} ((R-t(1-x))q - a_2 q + (R-tx)qV - a_1 qV dx \\
&+ \int_{\hat{x}_3}^{1} ((R-t(1-x))q - a_2 q)dx - P. \qquad (21)
\end{aligned}
$$

By substituting the equilibrium outcomes of the retail competition stage under MV, we find that SW^{M} depends on the specific value of f set by the regulator.

From (11) we obtain that when $f \leq R - 2t$, the profit of the firms and the consumer surplus level are:

$$
\begin{aligned}
\pi_i^{ML} &= \frac{q(R-f-t)(1+V)}{2}; \\
\pi_{ISP}^{ML} &= \frac{q(2f+t-2\mu q(1+V))(1+V)}{2}; \\
CS^{ML} &= \frac{tq\,(1-V)}{4}. \qquad (22)
\end{aligned}
$$

Taking this into account, social welfare (which can also be derived from 10) is:

$$
SW^{ML} = \frac{q}{4}\,(4R\,(1+V) - t(1+3V) - 4\mu q(1+V)^2). \qquad (23)
$$

Notice that this expression does not depend on f.

Now consider social welfare when $f > R - 2t$. From (9) we get the following intermediate results:

$$
\begin{aligned}
\pi_i^{MM} &= \frac{q(1+V)(t-V(2f-2R+t))^2}{2t\left(1+3V\right)^2}; \\
\pi_{ISP}^{MM} &= P+f\left(\frac{q(1+V)(t(1-V)+2(R-f)V)}{t(1+3V)}\right) \\
&\quad -\mu\left(\frac{q(1+V)(t(1-V)+2(R-f)V)}{t(1+3V)}\right)^2; \\
CS^{MM} &= \frac{q(3+V)(2f(1+V)-2R(1+V)+t(3+V))^2}{4t(1+3V)^2} \\
&\quad -\frac{q(f-R+2t)(1+V)(4t+3f(1+V)-3R(1+V))}{t(1+3V)^2}-P \qquad (24)
\end{aligned}
$$

As a result, the corresponding social welfare function is SW^{MM}, which we don't show here for simplicity. The first order condition of SW^{MM} with respect to f yields:

$$
f_R^{MM}=\frac{(2RV+t(1-V))(2\mu q(1+V)-t)}{\left(1+V\right)\left(t+4\mu qV\right)}. \qquad (25)
$$

This solution is valid as long as $R-2t<f_R^{MM}<\widehat{f}$, which is satisfied for $\overline{\mu}_1<\mu<\overline{\mu}_2$, where $\overline{\mu}_1=\frac{R-t}{2q(1+V)}$ and $\overline{\mu}_2=\frac{2RV+t(1-V-\sqrt{1+V})}{4qV\sqrt{1+V}}$. When $\mu<\overline{\mu}_1$, we find that $f_R^{MM}\leq R-2t$, and thus social welfare is as in (23). When $\overline{\mu}_1<\mu<\overline{\mu}_2$, the regulator sets f_R^{MM} and the society gets:

$$
SW^{MM}=\frac{q(4\mu qt+(t-2R)^2-tq\left(t+4(q\mu-R)\right)}{4\left(4\mu qV+t\right)}. \qquad (26)
$$

Finally, when $\mu>\overline{\mu}_2$, the regulator sets $f_R^{MH}=\widehat{f}$ to ensure that CPs reach a linking agreement. In this case, social welfare is:

$$
SW^{MH}=\frac{q((2R-t)(V+\sqrt{1+V})+2(R-\mu q(1+V)(1+\sqrt{1+V}))}{2\left(1+\sqrt{1+V}\right)}. \qquad (27)
$$

Proof of Proposition 3. We compare social welfare under SV and MV.

(i) When $\mu<\overline{\mu}_1$, the comparison of SW^{ML} and SW^S shows that $SW^{ML}>SW^S$ for $\mu<\frac{(4R-3t)}{4q(2+V)}$. Since $\frac{(4R-3t)}{4q(2+V)}-\overline{\mu}_1=\frac{t(1-V)+2RV}{4q(2+V^2)+12qV}>0$, we deduce that $SW^{MM}>SW^S$ for the relevant interval of μ.

(ii) When $\overline{\mu}_1<\mu<\overline{\mu}_2$, we find that $SW^{MM}-SW^S=\frac{q(4q\mu-2R+t)^2V}{4(t+4\mu qV)}>0$.

(iii) When $\mu>\overline{\mu}_2$, we conclude that $SW^{MH}>SW^S$ for $\mu<\hat{\mu}_R=\frac{t(1-\sqrt{1+V})+2V(2R-t)}{4qV(1+\sqrt{1+V})}$, where $\widehat{\mu}_R>\overline{\mu}_2$.

Proof of Proposition 4. For simplicity, assume that $\beta=0$ and consider that the value of the subscription fee is capped. Under SV, the ISP's profit $\pi_{ISP}^S=(R-\frac{3t}{2})q-\mu q^2$ does not depend on P and f. Under MV, all consumers MV if $f\leq R-2t$. Since $\pi_{ISP}^{ML}=P+(2-q)\,qf-\mu q^2\left(2-q\right)^2$ is increasing in f, the ISP sets $\widetilde{f}^{ML} = R - 2t$ to maximize its profit and gets $\widetilde{\pi}_{ISP}^{ML} = P + (2-q)\,q(\mu(q-2)q + R - 2t)$. When $R - 2t < f < \hat{f}$, the ISP sets f so as to maximize $\pi_{ISP}^{M} = P + fQ - \mu Q^2$, where Q is defined as in Proposition 2. The optimal termination fee is now:

$$\widetilde{f}^{MM} = \frac{(4\mu(2-q)(1-q)q + (4-3q)t)\,(2(1-q)R + qt)}{4(1-q)(2\mu\,(2-q)\,(1-q)\,q + (4-3q)t)} \tag{28}$$

and the ISP gets $\widetilde{\pi}_{ISP}^{MM}$. Comparing the results with those of Lemma 1 (Eq. 15), we obtain that $\widetilde{f}^{MM} > f^{MM}$. Indeed, when P is chosen by the ISP, it sets a lower termination fee and uses the subscription fee to extract part of the consumers' surplus created by the links. Finally, we find that $R - 2t < \widetilde{f}^{MM} < \hat{f}$ for $\widetilde{\mu}_1 < \mu < \widetilde{\mu}_2$, where

$$\widetilde{\mu}_2 = \frac{2\sqrt{2-q}(1-q)R - (8 - (6 + q\sqrt{2-q})t}{2q(2 - 3q + 2q)}. \tag{29}$$

This implies that for $\mu > \widetilde{\mu}_2$ the termination fee $\widetilde{f}^{MM}$ is so high that CPs don't reach a linking agreement. In this case, the ISP sets $\widetilde{f}^{MH} = \hat{f}$ to induce MV, and obtains $\widetilde{\pi}_{ISP}^{MH}$. Also notice that $\widetilde{\mu}_2 - \mu_2 = \frac{2\sqrt{2-q}t}{4(q-1)q} < 0$.

Finally, notice that $\widehat{f}$ should result in $\widetilde{\pi}_{ISP}^{MH} < \pi_{ISP}^{MH}$, since π_{ISP}^{MH} considers the profit maximizing P. Taking this into account, and defining $\widetilde{\mu}$ as the value for which $\pi_{ISP}^{S} = \widetilde{\pi}_{ISP}^{MH}$, it must be that $\widetilde{\mu} < \widehat{\mu}$.

Proof of Lemma 3. The fourth stage of the game in which CPs choose the advertisement time is as in Section 4.1. Hence, we initiate our analysis by considering the number of attributes they offer with SV and MV. For simplicity in this proof we assume that $\beta = 0$, which implies that $V = 1 - q$.

Single-Visit. Under SV, CP_i chooses the attributes q_i that maximize the profit in (6), which now includes the cost of increasing the number of attributes, that is $\pi_{ie} = \frac{((R-f)(q_i-q_j)+t(q_i+2q_j))^2}{9(q_i+q_j)t} - \frac{kq_i^2}{2}$.The first order condition of π_{ie} with respect to q_i, and after assuming symmetric firms, yields:

$$\begin{aligned} q^{SH} &= \frac{4(R-f)+t}{12k}; \\ \pi_e^{SH} &= \frac{(4(f-R)+11t)(4(R-f)+t)}{288k}. \end{aligned} \tag{30}$$

The expression for q^{SH} shows that the quality is decreasing in f. When $f \geq \frac{4R+t-12k}{4}$ CPs choose $q^{SH} \leq 1$ and the profits are π_e^{SH}. When $f < \frac{4R+t-12k}{4}$ there is a corner solution where $q^{SL} = 1$ and CPs obtain $\pi_e^{SL} = \frac{(t-k)}{2}$.

Multi-Visits. When CPs reach a linking agreement, it can be that all or just some consumers MV. Imagine first that all consumers MV, i.e., $f \leq R - 2t$. In Section 4, we obtained that for $f \leq R - \frac{2t}{q}$, the advertisement time in (10) is $a_{ie}^{ML} = f + \frac{1}{3}(\frac{2}{q_i} + \frac{4}{q_j} - 3)$ and the profit is $\pi_{ie}^{ML} = \frac{(q_i(3q_j-4)-2q_j)^2 t}{18 q_i q_j} - \frac{kq_i^2}{2}$. Importantly, this expression is decreasing in q_i, but the quality cannot be below $q_i = \frac{2t}{R-t}$ if we want to ensure that all consumers MV. Substituting this value in the advertising time we get $a_{ie}^{ML} = R - t$.

Imagine now that $R - \frac{2t}{q} < f \leq R - 2t$. From (11) we know that with $a_{ie}^{MM} = R - t$ all consumers MV and $\pi_{ie}^{MM} = \frac{q_i(2-q_j)(R-t-f)}{2} - \frac{kq_i^2}{2}$. With symmetric firms we obtain:

$$\begin{aligned} q^{MM} &= \frac{2\,(R-f-t)}{(R-f-t+2k)}; \\ \pi_e^{MM} &= \frac{2k\,(R-f-t)^2}{(R-f-t+2k)^2}. \end{aligned} \tag{31}$$

Observe that this solution holds as long as $q^{MM} < 1$, which happens for $f \in [R-2k-t, R-2t)$. When $f \in (0, R-2k-t)$ there is a corner solution with $q^{ML} = 1$. Indeed, f and k are so low that CPs choose the highest possible number of attributes and get π_e^{SL}.

Finally, consider that $f > R - 2t$, which implies that only some consumers MV. From (8) we obtain that the advertising time is
$a_{ie}^{MH} = \frac{f(2-q_i)(4-q_j)+2(4-q_i(2-q_j)-3q_j)R+(4-q_i)q_j t}{3q_iq_j-8q_j-8q_i+16}$. As a result, from the profit in (8) we obtain $\pi_{ie}^{MH} = \frac{(2(R-f)(2q_i+3q_j-q_iq_j-4)-q_jt(4-q_i))^2(2-q_j)q_i}{2(3q_iq_j-8q_j-8q_i+16)^2 t} - k\frac{q_i^2}{2}$.

The first order condition of π_{ie}^{MH} with respect to q_i, after considering symmetric CPs, yields q^{MH}, a long solution that we don't show for simplicity. Likewise, we don't present the resulting expression for π_e^{MH}.

With the above expressions we can compare the qualities with SV and MV. First notice that q^{SH}, q^{MM} and q^{MH} are decreasing with f (results for q^{MH} are obtained numerically). On the other hand, we find that $q^{SH} > 1$ for $f < \frac{4R+t-12k}{4}$ and that $q^{MM} > 1$ for $f < R - t - 2k$. Considering that the number of attributes is decreasing in f and that $k \leq t$, we obtain that q^{SH} equals 1 for a larger value of f than q^{MM}, and that $q^{SH} \geq q^{MM}$. Finally, notice that q^{MH} reaches its maximum value for $f = R - 2t$, in which case it is as q^{MM}, but both are smaller than 1.

Proof of Proposition 5.

From the proof of Lemma 3 we obtain that with SV the profit of CPs is:
(i) When $f \in [0, \frac{4R+t-12k}{4}]$, they set $q^{SL} = 1$ and obtain π_e^{SL}.
(ii) When $f \in (\frac{4R+t-12k}{4}, \overline{f}]$, they set $q^{SH} = \frac{4(R-f)+t}{12k}$ and obtain π_e^{SH}.
With MV their profit is:
(i) When $f \in [0, R-2k-t]$, they set $q^{ML} = 1$ and there is no MV.
(ii) When $f \in (R-2k-t, R-2t]$, they set q^{MM} and obtain π_e^{MM}.
(iii) When $f \in (R-2t, \overline{f}]$, they set q^{MH} and obtain π_e^{MH}.

To derive the CPs optimal linking strategy, we compare their profits under SV and MV. The next results are useful to identify the profit functions that have to be considered for each value of k:

(1) $(\frac{4R+t-12k}{4})-(R-2k-t)=\frac{1}{4}(5t-4k)>0$, which implies that for $f\in(0,R-2k-t)$ the relevant profit with SV is π_e^{SL} and that in this interval there is not MV.

(2) $(\frac{4R+t-12k}{4})-(R-2t)=\frac{3}{4}(3t-4k)$, which is positive if $k<\frac{3t}{4}$. Therefore, when $k<\frac{3t}{4}$ in the interval $f\in(R-2k-t,R-2t)$ we compare π_e^{SL} and π_e^{MM}, in $f\in(R-2t,\frac{4R+t-12k}{4})$ we compare π_e^{SL} and π_e^{MH}, and in $f>\frac{4R+t-12k}{4}$ we compare π_e^{SH} and π_e^{MH}[11]. On the other hand, when $k\geq\frac{3t}{4}$ in the interval $f\in(R-2k-t,\frac{4R+t-12k}{4})$ we compare π_e^{SL} and π_e^{MH}, in $f\in(\frac{4R+t-12k}{4},R-2t)$ we compare π_e^{SH} and π_e^{MM}, and in $f>R-2t$ we compare π_e^{SH} and π_e^{MH}.

Taking this into account, we find the following results:

(i) For $k\leq\frac{t}{2}$, CPs always choose SV and obtain π_e^{SL}. Indeed, for $k\leq\frac{t}{2}$ the region $f\in(\ R-2k-t,R-2t]$ doesn't exist. Moreover, in $f\in(R-2t,\overline{f})$ numerical simulations show that $\pi_e^{SL}>\pi_e^{MH}$.

(ii) For $\frac{t}{2}<k<\frac{3t}{4}$, CPs choose MV in the interval $f\in(R-2k-t,\widehat{f}_e)$, where $e\in\{1,2\}$. Indeed, in $f\in(R-2k-t,R-2t)$ we obtain that $\pi_e^{MM}>\pi_e^{SL}$; in $f\in(R-2t,\frac{4R+t-12k}{4})$ that $\pi_e^{MH}>\pi_e^{SL}$ if $f\leq\widehat{f}_1$, and in $f\in(\frac{4R+t-12k}{4},\overline{f})$ we obtain that $\pi_e^{MH}>\pi_e^{SH}$ if $f<\widehat{f}_2$.

(iii) For $\frac{3t}{4}\leq k<t$, CPs choose MV in the interval $f\in[R-2k-t,\widehat{f}_e]$, where $e\in\{1,2\}$. In $f\in(R-2k-t,\frac{4R+t-12k}{4})$ we find that $\pi_e^{MM}>\pi_e^{SL}$, in $f\in(\frac{4R+t-12k}{4},R-2t)$ we obtain that $\pi_e^{MM}>\pi_e^{SH}$, and in $f\in(R-2t,\overline{f})$ we find that $\pi_e^{MH}>\pi_e^{SH}$ for $f<\widehat{f}_2$.

Results for $\widehat{f}_e$ can only be obtained through numerical simulations and are shown in Panel A of Figure 4.

Results for Figure 4. We examine how the ISP sets the termination fee when q is endogenously determined. First we derive its optimal termination policy with SV and MV, and then we compare the results.

Single-Visit. As seen in Proposition 5, when the ISP sets $f<R-t-2k$ and $f>\widehat{f}_e$, CPs do not reach an agreement. From (6) we deduce that the ISP's profit is $\pi_{ISP}^S=P+qf-\mu q^2$. As full consumer participation is ensured with $P=(R-\frac{3t}{2}-f)q^{SH}$, this function simplifies to $\pi_{ISPe}^S=(R-\frac{3t}{2})q^{SH}-\mu(q^{SH})^2$, where $q^{SH}=\frac{4(R-f)+t}{12k}$. The first order condition of the profit function with respect to the termination fee yields:

$$f_e^{SH} = \frac{\mu(4R+t)-k(6R-9t)}{4\mu}; \tag{32}$$

$$\pi_{ISPe}^{SH} = \frac{(2R-3t)^2}{16\mu}. \tag{33}$$

Notice that an interior solution requires that $f_e^{SH}>\widehat{f}_e$. Otherwise, the ISP sets $f_e^{SL}=\widehat{f}_e$ and gets π_{ISPe}^{SL}. Also note that it must be that $f_e^{SH}>\frac{4R+t-12k}{4}$.

[11] Note that $\overline{f}-\frac{4R+t-12k}{4}>0$ for $k>\overline{k}$ (when $P=0$ we find that $\overline{k}=\frac{7t}{12}$). Hence, when $t/2<k<\overline{k}$ with SV the CPs sets $q_e^{SL}=1$ and get π_e^{SL} in the interval $f\in[0,\overline{f}]$. When $k\geq\overline{k}$ there is an interval $f\in[\frac{4R+t-12k}{4},\overline{f}]$ in which they set q_e^{SH} and get π_e^{MH}.

Indeed, for lower values, CPs set $q^{SL} = 1$ and the ISP gets $\pi^{SL}_{ISPe} = R - \frac{3t}{2} - \mu$. This happens for $\mu \leq \frac{2R-3t}{4}$.

Multi-Visits. When the ISP wants to induce MV, it should set $f \in (R - t - 2k, \widehat{f}_e)$. When $f \in (R - 2k - t, R - 2t)$, CPs set $a^{MM}_e = R - t$ and $q^{MM} = \frac{2(R-f-t)}{(R-f-t+2k)}$, and all consumers are induced to MV. Taking this into account, from (2) the ISP sets $P = \frac{(2-q)tq}{2}$ to guarantee full consumer participation and maximizes $\pi^{ML}_{ISPe} = P + (2-q)qf - \mu q^2(2-q)^2$. The numerical analysis shows that this expression is increasing in f. Thus, it sets $f^{ML}_e = R - 2t$ and obtains $\pi^{ML}_{ISPe} = \frac{4kt(t^2(2R-3t)+4kt(2R-3t-4\mu)+k^2(8R-12t))}{(2k+t)^4}$.

When $f \in (R-2t, \widehat{f}_e)$, CPs induce some consumers to MV, while the others SV. In this case, CPs set a^{MH}_e as in (8) and q^{MH}. From (2), we obtain that the ISP sets $P = \frac{(2-q)q(2(2-q)(R-f)-(4-q)t)}{2(4-3q)}$ to ensure full consumer participation and maximizes $\pi^{MM}_{ISPe} = P + fQ - \mu Q^2$, where $Q = \frac{(2(R-f)(1-q)+qt)(2-q)q}{(4-3q)t}$. The solution of this problem is f^{MM}_e, which can only be obtained numerically, and the ISP gets π^{MM}_{ISPe}. Also notice that $R - 2t \leq f^{MM}_e \leq \widehat{f}_e$ is satisfied for $\mu_{1e} \leq \mu \leq \mu_{2e}$, where the value for μ_{1e} and μ_{2e} are obtained numerically. When $f^{MM}_e > \widehat{f}_e$, the ISP sets $f^{MH}_e = \widehat{f}_e$ to guarantee that all consumers MV, and it obtains π^{MH}_{ISPe}.

We can now compare the profit of the ISP with SV and MV. Panel B in Figure 4 shows the optimal termination fees when parameter values are $R = 5$, $t = 1$ and $k = 0.75$. When $\mu \leq \mu_{1e}$, we obtain that $\pi^{ML}_{ISPe} > \pi^{SL}_{ISPe}$ and as result the ISP sets $f^{ML}_e = R - 2t$. When $\mu_{1e} < \mu < \mu_{2e}$, we find that $\pi^{MM}_{ISPe} > \pi^{SH}_{ISPe}$ and it sets f^{MM}_e. Finally, when $\mu > \mu_{2e}$ we obtain that $\pi^{MH}_{ISPe} > \pi^{SH}_{ISPe}$ for $\mu < \widehat{\mu}_e$. Thus, when $\mu_{2e} < \mu < \widehat{\mu}_e$, the ISP sets $f^{MH}_e = \widehat{f}_e$ and for $\mu > \widehat{\mu}_e$ it sets f^{SH}_e.