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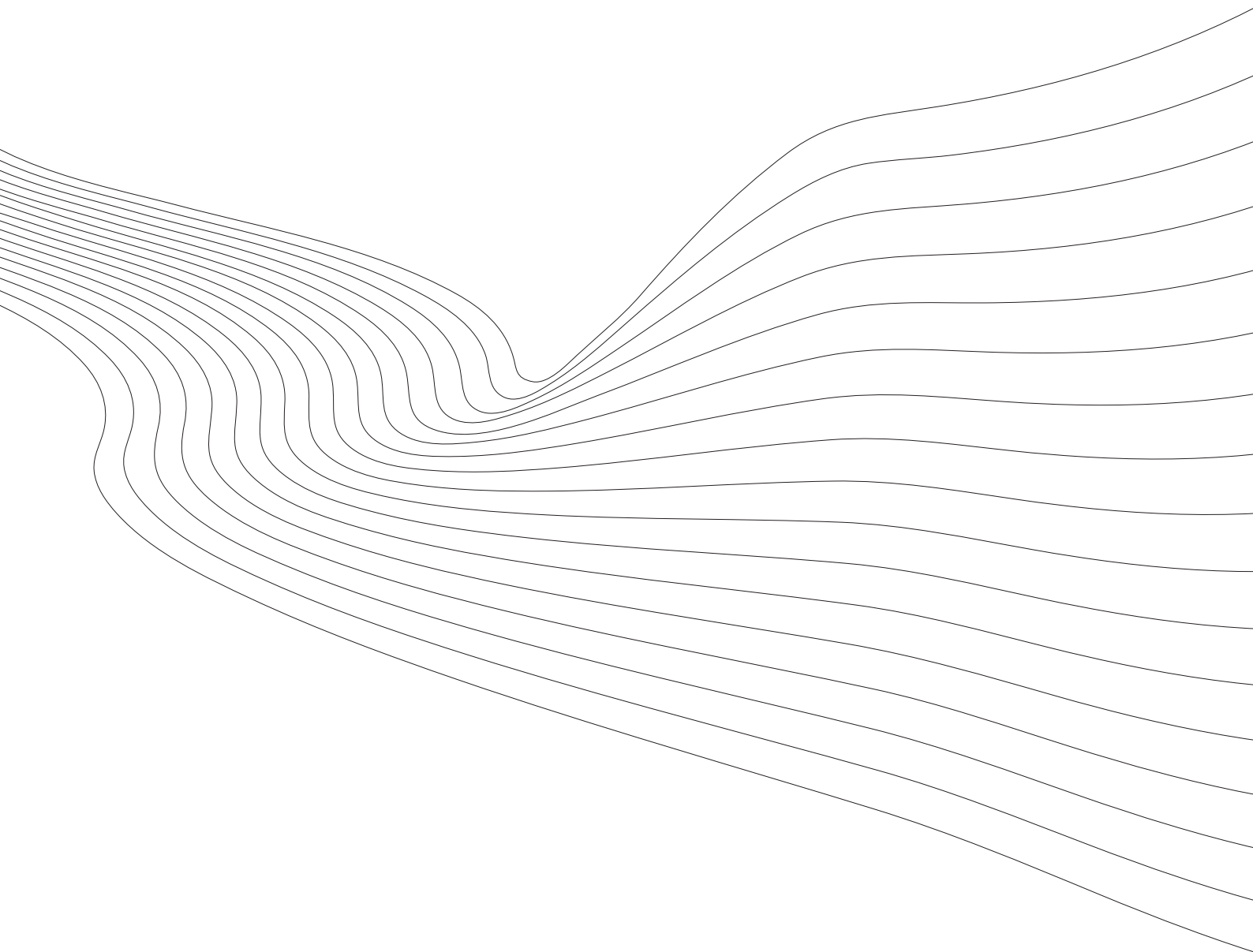
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KOF Working Papers

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Network Neutrality, Access to Content and Online Advertising*

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Abstract

We investigate the implications of Network Neutrality regulation for Internet fragmentation. We model a two-sided market, where Content Providers (CPs) and consumers interact through Internet Service Providers (ISPs) and CPs sell consumers' attention to advertisers. Under Network Neutrality, CPs can have their traffic delivered to consumers by ISPs for free, while in the Unregulated Regime they have to pay a (non-discriminatory) termination fee. In our model multiple impressions of an ad on a consumer are partially wasteful. Thus, equilibrium ad rates decrease when the audiences of CPs overlap. We show that universal distribution of content is always an equilibrium when Network Neutrality regulation is in place. In contrast, when competition among CPs strongly reduces their profits, in the Unregulated Regime ISPs can use termination fees to induce fragmentation and extract CPs' extra profits. This occurs when repeated impressions of an ad rapidly lose value and consumers care for content availability to a relatively small extent. Our results suggest that the Unregulated Regime is never superior to Network Neutrality from a consumer surplus and social welfare point of view.

Keywords: Network Neutrality, two-sided markets, Internet, advertising, fragmentation

JEL Classification: L1, D43, L13, L51

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1 Introduction

Traditionally, the Internet has been characterized by the Network Neutrality principle. This principle has various practical implications. In particular, it implies a zero-price and a non-discrimination rule (Schuett, 2010). The former refers to the fact that Internet Service Providers (hereafter, ISPs) should not collect fees from Content Providers (hereafter, CPs) to deliver (or “terminate”) data to final users, while the latter specifies that ISPs should treat all traffic equally.¹ Presently, there is a very important policy debate concerning the extent to which the Network Neutrality principle should be codified in formal regulation. Opponents assert that allowing greater pricing flexibility to ISPs is vital in order to ensure a more efficient use of bandwidth and strengthen incentives for investment in network infrastructure. Proponents argue instead that Network Neutrality regulation is necessary to preserve plurality on the Internet, alongside incentives for content innovation (Krämer, Wiewiorra and Weinhardt, 2013).

The above issues have received considerable attention in previous literature (which we review in Section 2 below). There is, however, another aspect of Network Neutrality that has been much less scrutinized thus far. Namely, the implications of (relaxing) a zero-price rule for Internet fragmentation. Indeed, while termination fees can improve efficiency, there are concerns that they could also lead to a fragmented Internet, with parts of the consumer base being unable to access content available to others (Lee and Wu, 2009, Werbach, 2009).

Fragmentation is not uncommon in the history of digital platforms.² Thus, the fact that the Internet is a universally connected network might be subject to change. Policymakers are clearly sensitive to the issue. In the US, the FCC adopted a policy framework adhering to the principle that “ISPs should not block lawful content, applications and services, subject to reasonable network management” (FCC, 2010). The European Commission recently stated that ISPs should “not block, slow down, degrade or discriminate against specific content, applications or services or specific classes” (EC, 2013). Furthermore, MEP Marietje Schaake recently expressed concerns that “in the absence of regulation, Internet providers could block access to certain news or entertainment sites because of their financial interests” (EUObserver.com, retrieved June 2013). As a matter of fact, some countries have already adopted legislation forbidding ISPs to charge termination fees to content providers.

Our objective in this paper is to shed some light on this issue. To keep the analysis as

¹The current practice is that CPs pay a fee to the backbone ISP that provides them access to the Internet, but they do not pay the ISPs to terminate their traffic to end users.

²In the television sector, for instance, exclusivity contracts for content are commonplace. Concerning the Internet, Krämer, Wiewiorra and Weinhardt (2013), report the cases of Madison River Communications attempting to block VoIP traffic and of Comcast restricting P2P traffic.

simple and transparent as possible, we consider a model with two CPs and analyze both the case of a monopolist ISP and of two competing ISPs. An ISP is a platform connecting CPs to consumers and a CP is a platform selling consumers’ attention to advertisers. Consumers pay the ISP for connection to the Internet and browse content free of charge. We study two regulatory regimes: under Network Neutrality, a zero-price rule is enforced and CPs do not pay for traffic termination. In the Unregulated Regime, instead, ISPs make access to their subscribers conditional on the payment of a termination fee.³ In a competitive environment, one can expect ISPs to have the incentive to distribute some contents under exclusivity arrangements, in order to differentiate themselves from rivals and/or to insulate content they produce from competition. This is common in other media markets such as television (Weeds, 2012) and may bring to fragmentation. In this paper, however, we ignore exclusive contracts and look at another possible rationale for fragmenting the network, which is directly related to competition on the online advertising market.

It is well recognized that the Internet is a two-sided market bringing together consumers and advertisers. Yet, to the best of our knowledge, previous literature on Network Neutrality has never explicitly modeled the advertising side. In contrast, we model revenues collected by CPs as arising from equilibrium outcomes in that market. Our model accounts for the stylized fact that the marginal value of impressing a consumer with an ad decreases with the number of times she is exposed to it. This is because an ad that reaches a consumer that is already informed about a product could be (at least partially) wasted, since no more information could be elicited from it.⁴ As suggested by Athey, Calvano and Gans (2013), the fact that consumers consult several contents in a short time frame (which is common on the Internet) means that advertisers placing ads on multiple CPs run the risk that their impressions are viewed by the same consumer many times. Consequently, the willingness to pay for advertising slots by multi-homing advertisers diminishes when audiences overlap.⁵ Indeed, there is evidence that, while advertisers place increasingly large quantities of ads online, competition among publishers keeps advertising rates low.⁶

³Our definition of Network Neutrality is thus simply as a zero-price rule for traffic termination by so-called “access ISPs” (see Krämer, Wiewiorra and Weinhardt, 2013). We disregard service tiering and quality discrimination in our model, but discuss them in Section 6.

⁴See, for example, Calvano and Jullien (2011), Anderson, Foros and Kind (2011), Athey, Calvano and Gans (2013) and Ambrus and Reisinger (2006).

⁵As a response, Internet platforms introduce tracking technologies that reduce within-outlet waste. However, if cross-outlet tracking is imperfect (or, in the extreme, absent as we assume) the problem is not solved.

⁶Todd Haskell, vice-president of advertising for the New York Times, recently stated that “rates for online-video ads have not been increasing though publishers have more demand than supply”. He also stated that publishers may seek differentiation from competitors as a way to “avoid the downward commoditized price positioning” of ad slots (WSJ.com, 2013, “If Media’s Future Is Online, Where Are the Profits?”, retrieved June 2013) .

As long as competition to attract advertisers reduces profits, one would expect CPs to try to soften it by targeting different audiences. However, such an equilibrium may prove difficult to sustain, especially if consumers can be reached for free. We show that, by strategically setting non-discriminatory termination fees, ISPs may fragment the Internet. In turn, we underline an important link between Network Neutrality, Internet fragmentation and competition on the advertising market.

The results we obtain run as follows. In the Network Neutrality regime, ISPs have no role in shaping network configuration. There is always an equilibrium where all CPs access all consumers (to which we refer as “Universal Connection”). However, when the profitability of competitively priced ad spaces is low enough, there also exists an equilibrium in which CPs decide to serve only consumers of different ISPs (to which we refer as “Total Fragmentation”). This takes place when repeated impressions of an ad on the same consumer rapidly lose value.

In the Unregulated Regime, the presence of termination fees significantly changes the forces shaping the network configuration. Since they can recover CPs profits via the termination fee, ISPs behave as editors, caring about the profitability of the content they carry. Hence, when competition strongly reduces ad rates, ISPs have an incentive to discard Universal Connection and induce Total Fragmentation as the unique equilibrium. This can be done by raising termination fees to a high enough level. An equilibrium entailing Universal Connection can nonetheless exist when the impact of competition on advertising profits is limited.

Comparing the two regulatory regimes, our results suggest that not adopting the zero-price rule makes universal distribution of content less likely. More precisely, with Network Neutrality, Universal Connection is always an equilibrium. In contrast, in the Unregulated Regime, Total Fragmentation is the unique equilibrium when competition among CPs strongly impacts their profitability. However, a change in the regulatory regime does not necessarily imply a change in network configuration. First, when the impact of competition on advertising profits is small, Universal Connection is the only equilibrium, even without Network Neutrality. Second, if competition among CPs is strong, Total Fragmentation can take place even if Network Neutrality is maintained. It follows that, although Network Neutrality regulation helps preserving universal access to online content, the extent to which repeated ad impressions lose value plays an important role in shaping the network configuration, regardless of the regulatory regime.

In terms of welfare implications, our analysis suggests that, since it maximizes gross surplus at both ends of the market (i.e. for consumers and advertisers), Universal Connection is the most desirable configuration for society as a whole. Hence, Network Neutrality should be the preferred regulatory regime, at least when competition has a significant impact on

CPs' profits. In addition, without Network Neutrality, ISPs are unambiguously better off, while CPs are unambiguously worse off. Nevertheless, the outcome of our welfare analysis may be sensitive to some of our assumptions and should therefore be interpreted with caution. We provide a discussion of some of the main aspects that are ignored in the formal model in Section 6.

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature. Section 3 presents the model, which is solved in Section 4 for the case of a monopolistic ISP and in Section 5 for a duopoly of ISPs. Section 6 discusses some of the main assumptions we have taken. Section 7 presents some policy implications of our results. Section 8 concludes.

2 Literature

There is a wide debate on Network Neutrality that has only recently been formally analyzed from an economic perspective.⁷ The main focus of previous literature has been on service tiering and investment in content and network infrastructure. Service tiering by ISPs, i.e., provision to CPs of different service qualities at different prices, is often advocated as a way to better deal with congestion. Hermalin and Katz (2007) study the desirability of traffic discrimination. When an ISP is free to discriminate, more attractive contents purchase higher quality of service. The welfare comparison among the Unregulated Regime and Network Neutrality is however ambiguous.⁸ Choi and Kim (2010) consider service tiering and investment incentives for a monopolist ISP and for CPs in different regulatory regimes. In the long run, ISP and CPs can invest more or less under the discriminatory regime. Again, no regulatory framework dominates the others. Bourreau, Kourandi and Valletti (2012) study a similar issue in a model with two competing ISPs. Under discrimination, ISPs have larger investment incentives, more content providers are active and there is less congestion. Hence, the discriminatory regime is welfare superior to Network Neutrality. Economides and Hermalin (2012) show that the socially optimal configuration maximizes contents delivered to consumers. Differently from Bourreau, Kourandi and Valletti (2012), departing from Network Neutrality through a tiering service can either increase or decrease the variety of distributed content and thus welfare. In the long run, they also show, contrary to Choi and Kim (2010), that departing from Network Neutrality unambiguously increases the incentives of the ISP

⁷See Lee and Wu (2009) for a discussion on the economic issues concerning Network Neutrality. See Schuett (2010) and Krämer, Wiewiorra and Weinhardt (2013) for a review of the literature.

⁸Choi, Jeon and Kim (2012) study a similar issue with two interconnected ISPs. They show that the advantage of Network Neutrality regulation crucially depends on the business model of the content providers, since this affects the quality level provided by ISPs under different regimes.

to invest in network infrastructure. However, once both dynamic and static effects are taken into account, the net welfare effect is not clear.

Differently from the above papers, we consider Network Neutrality as a zero-price rule: it requires that ISPs charge no fees to CPs in order to terminate their traffic to final users. This definition of Network Neutrality is also used in Economides and Tag (2012). They concentrate on pricing issues linked to the two-sidedness of the market that could arise due to a departure from Network Neutrality. Considering a duopoly of ISPs, they find that, when content providers value consumers more than consumers value contents, welfare increases under Network Neutrality. Instead, consumer surplus always decreases. This is because competition for consumers is less intense than under no regulation, as cross-group externalities are taken into account by the platform. Musacchio, Schwartz and Walrand (2009) analyze a similar issue in a model where ISPs and CPs can also invest in network quality. They find that Network Neutrality has ambiguous welfare implications.

As mentioned in the Introduction, previous papers on Network Neutrality treat profitability of content providers as exogenous. In our paper it results from platform competition on the advertising market. A novelty of our model is therefore that it is at the intersection between the literature on Network Neutrality and that on online advertising markets. Ambrus, Calvano and Reisinger (2013) and Anderson, Foros and Kind (2013) build models of media platform competition where both consumers and advertisers multi-home. A common finding is that platforms have monopoly power over single-homing consumers, but can only charge the incremental value of ad impressions for multi-homing consumers. Our model captures the same key effect.⁹ This, we show, drives the strategic use of termination fees by ISPs.

Furthermore, our paper is among the very first to analytically study the link between termination fees and Internet fragmentation. In a recent paper, Kourandi, Krämer and Valletti (2013) (hereafter, KKV) also consider this question. There are some important differences between our approach and theirs. First of all, their main focus is on exclusive contracts between ISPs and CPs. In contrast, we study how fragmentation can result simply from allowing ISPs to impose non-discriminatory termination fees. KKV also model a termination fee but, differently from us, assume it is exogenous.¹⁰ Thus, the two papers investigate the link between pricing regulation and Internet fragmentation in a complementary way. Another difference is that in our model connection decisions are made simultaneously by

⁹In the media market, Dukes and Gal-Or (2003) study a related issue. They show that commercial media have incentives to minimally differentiate among themselves, in order to induce less informative advertising by producers. Hence, producers compete less strongly on the product market, and commercial media can ask for higher advertising fees.

¹⁰This gives rise to a slightly different interpretation of Network Neutrality than ours: in their paper it entails either zero termination fees or zero termination fees and zero-transfers for exclusive contracts.

CPs. In KKV, ISPs contract instead sequentially with CPs for exclusivity. In addition, we explicitly model the advertisers side of the market. KKV assume that the revenue per impression for exclusive consumers is higher than for non-exclusive ones. However, they do not model the forces underpinning this assumption. The differences mentioned above affect the results. Differently from KKV we find that Universal Connection is always an equilibrium under Network Neutrality. In our model, with Network Neutrality ISPs have no instrument to influence CPs' connection decisions. On the contrary, in KKV a CP that has signed an exclusivity contract with an ISP cannot connect to the other one. Furthermore, they find that content complementarity makes Total Fragmentation (resp. Universal Connection) more (less) likely in the Unregulated Regime. We find the opposite. Finally, KKV find, contrary to us, that Universal Connection is not always socially desirable. This is due to the fact that our framework allows us to evaluate advertiser surplus and take it into consideration when computing total welfare.

3 The Model

3.1 Setup

We consider a setting with two ISPs, indexed by $i = A, B$, and two CPs, indexed by $j = 0, 1$. An ISP is a platform connecting consumers to CPs, and a CP is a platform connecting consumers to advertisers.¹¹ ISPs and CPs are independent firms. We compare two alternative regulatory regimes: one in which Network Neutrality regulation is in place and one in which it is not, referred to as the Unregulated Regime. In the former case, ISPs have to grant access to their subscribers to all CPs for free: we consider Network Neutrality as a zero-price rule (see, e.g., Schuett, 2010). In the latter regime, ISPs can impose termination fees to CPs.

Internet Service Providers. ISPs are located at the extremes of a Hotelling line: ISP $i = A$ is located at point 0 and ISP $i = B$ at point 1.¹² ISP i sets a subscription fee a_i for consumers who want to join its network. In the Unregulated Regime, ISP i also sets a termination fee F_i for CPs that want to reach its consumers. F_i is exclusionary: a CP can access ISP i 's consumer base only if agrees to pay it. There is no restriction on the sign of termination fees. In the Network Neutrality regime, CPs can freely access both ISPs, hence

¹¹In our model, ISPs are so-called “access” ISPs, that provide connection between final users and the Internet backbone (Krämer, Wiewiorra and Weinhardt, 2013). We do not model such backbone, since our focus is on termination fees.

¹²Horizontal differentiation between ISPs may be the consequence of uneven geographical coverage and/or of bundling of Internet and other telecom services.

$F_i = 0$. All fees are non-discriminatory and non-contingent. The profit function of ISP i is

$$\pi_i = a_i q_i + \sum_{j=0,1} F_j I_{ij} \quad i = A, B$$

where q_i is the number of consumers connected to ISP i and I_{ij} is an indicator function, such that $I_{ij} = 1$ if CP j acquires access to ISP i 's consumers and $I_{ij} = 0$ otherwise.

Consumers. There is a large mass (normalized to one) of consumers uniformly distributed on the interval $[0, 1]$. Consumers connect to one and only one ISP.¹³ The utility U_i a consumer located in $x \in [0, 1]$ gets from connecting to ISP i is

$$U_i(x) = Z + \Delta_i - t|x - l_i| - a_i \quad i = A, B \quad (1)$$

where Z is the gross surplus from accessing the Internet, assumed large enough that all consumers connect to an ISP. t is the transportation cost on the Hotelling line and l_i represents the ISP's position on the Hotelling line, so $l_A = 0$ and $l_B = 1$. Hence, $t|x - l_i|$ is the disutility for consumer x from not subscribing to the ISP which is closest to her preferences. Δ_i represents the utility consumers get from browsing contents available on ISP i . We assume the following

$$\Delta_i = \begin{cases} 0 & \text{if no CP is available on ISP } i \\ \delta & \text{if one CP is available on ISP } i \\ \delta(1 + \gamma) & \text{if both are available} \end{cases}$$

with $\delta, \gamma \geq 0$. The term δ represents the utility consumers obtain from accessing a single content, while $\delta\gamma$ captures the extra utility of accessing an additional one. Hence, δ can be interpreted as the value consumers attribute to content availability in absolute terms, while γ represents the degree of complementarity among the two contents. We do not assume any a priori difference among contents and we allow them to be either substitutes ($\gamma < 1$), complements ($\gamma > 1$) or independent ($\gamma = 1$). For example, two general interest news sites could be substitute contents, whereas a general and a specialized one (covering e.g. sports, fashion, art, etc.) could be seen as complementary. We do not endogenize consumers' demand

¹³We assume consumers subscribe to just one platform to access the Internet, as it is currently the most widespread practice. It is however conceivable that consumers might multi-home if some contents were accessible only through a given platform. Our results still hold if the number of multi-homing consumers is not too large.

for contents and simply assume that each consumer visits all available contents once.¹⁴¹⁵ We ignore any (dis)utility from ads (see Section 6 below for further discussion on the topic). We assume that the market is covered and that the demand for each ISP is positive, i.e. $\sum_i q_i = 1$ and $q_i > 0 \forall i$.

Net consumer surplus (CS) can be computed as

$$CS = \int_0^{q_A} (Z + \Delta_A - tx - a_A) dx + \int_{q_A}^1 (Z + \Delta_B - t(1-x) - a_B) dx$$

and can be written as

$$CS = Z + \sum_{i=A,B} (\Delta_i - a_i) q_i + \frac{t}{2} - tq_B - tq_A^2$$

Content Providers. Each CP provides free content to consumers but charges advertisers that place ads on it. A CP j charges a *per-impression* price p_j to an advertiser if and only if a consumer is exposed to the ad while browsing its content. We assume there is no cost of providing ad spaces and that CPs set a uniform price for advertisers. We assume each visit by a consumer on a given content brings to an impression. Hence, the volume of impressions for an ad put on CP j is equal to q_j , which is the number of consumers connected to the ISPs distributing j 's content, i.e.

$$q_j = \sum_{i=A,B} q_i I_{ij} \quad j = 0, 1$$

The profit of CP j is

$$\pi_j = d_j p_j q_j - \sum_{i=A,B} F_i I_{ij} \quad j = 0, 1$$

where d_j is the number of advertisers on CP j .

A CP can connect to either no ISP, only one or both of them. CPs simultaneously decide which consumers they want to be available to by comparing profits under all network configurations. In so doing they take as given the termination fees (F_A, F_B) and the decision made by the rival CP. We assume that if a CP is indifferent between connecting to an ISP

¹⁴More precisely, we assume that each consumer visits all available contents a given number of times N , that we assume without loss of generality to be equal to 1. This same assumption is used by, *e.g.*, Bourreau, Kourandi and Valletti (2012), Choi, Jeon and Kim (2012) and Krämer and Weiwiorra (2012).

¹⁵In a more complex model, one could assume the presence of several differentiated contents. Moreover, we could relax the hypothesis that consumers visit all CPs. However, as far as a subset of those CPs has overlapping audiences, the forces we describe in the paper would still be relevant. We return to this issue in Section 6.

or not, it does so. A given network configuration arises at equilibrium when no CP finds a profitable unilateral deviation.

Advertisers. There is a mass of size one of advertisers. Their willingness-to-pay for ad slots crucially depends on the number of outlets they can use to reach a given consumer (as we explain below). Let V' denote the gross surplus (i.e. the increase in the expected value of sales due to the consumer seeing the ad) produced by reaching a consumer through a single CP. We denote by V'' the additional gross surplus produced by reaching the same consumer through an additional CP. Recent literature on online advertising suggests that ads seen multiple times are partially wasteful (Calvano and Jullien, 2011), since they reach already informed consumers and are therefore squandered together with their attention.¹⁶ Formally, this means that $V' \geq V'' \geq 0$.

Let us now provide a micro-foundation for this advertising model, following Anderson and Coate (2005) and Ambrus and Reisinger (2006). Assume that each advertiser is a monopolist producer of a differentiated good of quality k . Per each good, there exists a fraction α of consumers with willingness-to-pay equal to $k > 0$, while the rest has valuation zero. All consumers are impressed with all ads placed on a content when visiting it. Since each producer has monopoly power, it imposes a price equal to k . When (and only when) a consumer with a positive valuation for the good becomes informed, she buys it. The consumer is informed when she is impressed with an ad she pays attention to. There is a probability $\beta \in [0, 1]$ that a consumer pays attention to an ad when impressed. Hence, the expected value of impressing a consumer with an ad for the first time is

$$V' = k\alpha\beta$$

A consumer can be impressed by the same ad for a second time while visiting another content. The expected value of impressing the consumer for a second time is

$$V'' = k\alpha(1 - \beta)\beta$$

that is, the expected value given that the consumer did not pay attention when impressed for the first time (note that an impression which the consumer has already paid attention to has no value since the consumer is already informed and has already bought the product). Clearly, we have

$$V' \geq V'' \geq 0$$

¹⁶Athey, Calvano and Gans (2013) estimate that more than two thirds of the ads in large campaigns are wasted, hitting the same receivers more than 10 times.

In the following, we will use the reduced form for the gross utility of an advertising slot for advertisers.¹⁷

A CP j sells ads at a uniform per-impression price p_j .¹⁸ Advertisers can buy ad spaces from none, one or both CPs. We assume that, if an advertiser is indifferent between placing ads on a CP and not, it does so. Suppose an advertiser multi-homes, buying ad spaces from both content providers. Its total surplus would be

$$V' \bigcup_{j=0,1} q_j + V'' \bigcap_{j=0,1} q_j - \sum_{j=0,1} p_j q_j$$

where $\bigcup_{j=0,1} q_j$ denotes the mass of consumers accessing at least one content and $\bigcap_{j=0,1} q_j$ denotes the number of consumers that access both contents. If all advertisers multi-home each consumer accessing at least a CP ($\bigcup_{j=0,1} q_j$) is impressed at least once by each ad. Consumers that access both CPs ($\bigcap_{j=0,1} q_j$) are impressed twice. Suppose instead the an advertiser single-homes, buying an ad space only from CP j . Only consumers having access to j are impressed and its total surplus would be

$$(V' - p_j) q_j \quad j = 0, 1$$

Obviously, the surplus is zero if no ad space is bought. Taking as given the network configuration and prices p_j , the advertiser will choose the option that guarantees the highest surplus. We may therefore compute total advertisers surplus as

$$AS = \sum_{j=0,1} d_{sj} (V' - p_j) q_j + d_m \left(V' \bigcup_{j=0,1} q_j + V'' \bigcap_{j=0,1} q_j - \sum_{j=0,1} p_j q_j \right)$$

where d_{sj} is the number of advertisers that single-home on CP j and d_m is the number of

¹⁷We could also micro-found our model using targeting. The setup would be similar to the present one. We would nonetheless assume that consumers pay attention to an ad with probability one when impressed. Moreover, CPs are endowed with an identical advertising technology, that allow them to identify a consumer (i.e. discover which good she is interested in) with probability $\beta \in [0, 1]$. If the consumer is identified, she gets impressed with the ad intended for the good she is interested in. The consumer buys the good only once, and after the first time she is impressed by the ad. Hence, while all first impressions generate a sale of the product, this is not the case for second impressions. Some of the second impressions are thus worthless for advertisers. In this model, $V' = k\alpha\beta$ would be the expected value for an advertiser of reaching a consumer through a CP, and $V'' = k\alpha(1-\beta)\beta$ the expected value of reaching a consumer through an additional CP. Formally, the profit function of CPs now slightly change on the cost side compared to the attention model in the main text. Indeed, now only βq_j consumers (and not all consumers, like in attention model) of CP j are impressed by the ad. Except for these slight modifications, our analysis would be the same.

¹⁸We assume that there is no across-outlet tracking. Hence, a CP has no knowledge on whether a given consumer has already been impressed with the ad while browsing the rival's content or not. This means that prices p_j cannot be discriminated accordingly.

advertisers that multi-home.

Welfare. Social welfare SW is the sum of consumer surplus, advertisers surplus and profits of ISPs and CPs. Thus

$$SW = CS + AS + \sum_{i=A,B} \pi_i + \sum_{j=0,1} \pi_j$$

Social welfare coincides with the gross surplus generated by connections at the two ends of the market, i.e. with the sum of gross surplus for consumers and advertisers. Indeed, payments collected by ISPs and CPs are simply transfers from other players and cancel out in SW . Replacing CS , AS , $\sum_{i=A,B} \pi_i$ and $\sum_{j=0,1} \pi_j$ in SW , we get

$$SW = Z + \sum_{i=A,B} \Delta_i q_i + \frac{t}{2} - tq_B - tq_A^2 + \sum_{j=0,1} d_{sj} V' q_j + d_m \left(V' \bigcup_{j=0,1} q_j + V'' \bigcap_{j=0,1} q_j \right)$$

We can conclude the following

Lemma 1 *Universal Connection is the socially-optimal network configuration and multi-homing is the socially-optimal behavior by advertisers.*

Proof. The fact that each CP is connected to both ISPs implies that $q_j = 1 \forall j$, as consumers have access to all contents, irrespectively of the ISP they subscribe to. It also implies that $q_A = q_B = 1/2$, hence total transport cost $\frac{t}{2} - tq_B - tq_A^2$ is minimized. SW is strictly increasing in $\sum_{i=A,B} \Delta_i q_i$, which is maximized when $I_{ij} = 1 \forall i, j$. It is also optimal to have all advertisers multi-home, since SW increases in the number of ad impressions to consumers. ■

Timing and definition of equilibrium. The timing of the game is as follows:

1. In the Unregulated Regime, ISP A and B simultaneously set termination fees F_i . In the Network Neutrality regime, F_i is restricted to zero. Having observed fees F_i , CPs simultaneously decide which ISP to connect to (if any).
2. ISP A and B simultaneously set subscription fees a_i . CPs simultaneously set (per-impression) prices p_j for their ad spaces. Advertisers buy ad spaces from CPs.
3. Consumers connect to their preferred ISP and visit the available CPs, getting exposed to the ads.

A subgame-perfect equilibrium of the game is a set of fees, prices, connection decisions and demands such that, at each stage, no player wants to deviate given the choice of other players

and what has been decided at previous stages. We assume all agents have perfect foresight. The model is solved by backward induction.

4 ISP monopoly

In order to gradually introduce the forces at work in our framework, we now study a simplified scenario in which only one ISP (say, A) is active. We disregard the presence of ISP B . We postpone the description of the the fully-fledged version of the model with competing ISPs to Section 5 below.

4.1 Stage 3

At stage 3, consumers decide whether to subscribe to ISP A or stay out of the market. Only consumers that are sufficiently close to A (i.e. with low enough x) participate.¹⁹ To compute consumers' demand, we define the marginal consumer \underline{x} who is indifferent between connecting to ISP A and not accessing the Internet at all. From $U_A(x) = 0$, we find

$$\underline{x} = \frac{Z + \Delta_A - a_A}{t}$$

Demand for ISP A is thus $q_A = \underline{x}$.

4.2 Stage 2

At stage 2, ISP A decides the subscription fee a_A maximizing $\pi_A = q_A a_A + \sum_j F_A I_{Aj}$, where $q_A = \underline{x}$. Using the first order condition $\frac{\partial \pi_A}{\partial a_A} = 0$, we find

$$a_{Amon}^* = \frac{Z + \Delta_A}{2}$$

By substitution, we obtain equilibrium demand and profits:²⁰

$$q_{Amon}^* = \frac{Z + \Delta_A}{2t} \quad \pi_{Amon}^* = \frac{(Z + \Delta_A)^2}{4t} + \sum_j F_A I_{Aj}$$

Not surprisingly, both subscription fee and demand are increasing in Δ_A and Z . Demand is also decreasing in t . Hence, taking termination fee F_A as given, profits are increasing in Z and Δ_A , and decreasing in t .

¹⁹We here relax the covered market assumption.

²⁰Since we have assumed that $1 \geq q_{Amon}^* > 0$, this implies that $\delta(1 + \gamma) \leq 2t - Z$ holds.

We will now describe how CPs set prices of ad spaces. Suppose to be in the Universal Connection configuration. The equilibrium is such that CPs charge a per-impression price $p_j = V''$ $j = 0, 1$ and advertisers multi-home. To see why, consider that a higher price could profitably be undercut by the rival CP, winning it the entire market. This is because advertisers would optimally single-home on the cheapest outlet, still reaching all available consumers. On the other hand, there is no point in charging less than V'' . This is because advertisers would anyway multi-home, since the price per impression would be lower than the value of an additional impression V'' .²¹ Now, suppose CP j were the only one available to subscribers at ISP A . Since the CP has exclusive access to consumers attention, it can set monopoly price $p_j = V'$, capturing the entire advertiser gross surplus. Obviously, advertisers only place ads on a CP with a positive market share. The above discussion introduces us to Lemma 2, presenting CPs' profits at stage 2. We provide in its proof a more formal and complete description of how ad space prices are determined.

Lemma 2 *In equilibrium, advertisers buy ad slots from all CPs that have access to consumers. Advertising profits π_{jmon}^* of CP j , conditionally on its connection status, are reported in Table 1.*

π_{0mon}^*	π_{1mon}^*	A	No
A		$V'' q_{mon}^{++} - F_A$ $V'' q_{mon}^{++} - F_A$	0 $V' q_{mon}^+ - F_A$
No		$V' q_{mon}^+ - F_A$ 0	0 0

$$\text{where } q_{mon}^{++} = \frac{Z+\delta(1+\gamma)}{2t} \text{ and } q_{mon}^+ = \frac{Z+\delta}{2t}$$

Table 1: Monopoly model: advertising profits π_{jmon}^* of CP j , conditionally on its connection status.

Proof. See the Appendix. ■

²¹This crucially depends on multi-homing by advertisers and the diminishing value of repeated impressions. If multiple impressions did not lose value, competition among CPs would have no impact on prices of ad spaces. If multi-homing of advertisers were ruled out, the equilibrium price would be equal to the marginal cost of providing ad spaces, which is zero by assumption.

4.3 Stage 1

At stage 1, ISP A sets the termination fee F_A and CPs decide whether to connect or not. This determines the network configuration. We now present the subgame-perfect equilibria of the game. We begin from the benchmark case of Network Neutrality. Next, we consider the Unregulated Regime. In the following, we denote with superscript N the equilibrium variables under Network Neutrality, and with superscript U those under the Unregulated Regime.

4.3.1 Benchmark: Network Neutrality

In the Network Neutrality regime, ISP's profits are simply given by revenues collected from subscription fees on the consumers' market

$$\pi_{Amon}^N = \frac{(Z + \Delta_A)^2}{4t}$$

We now study CPs' connection decisions, and derive the corresponding configuration of the network. Elaboration from Table 1 leads to the following

Proposition 1 *Suppose there is a monopolist ISP. In the Network Neutrality regime there exists a unique subgame-perfect equilibrium entailing Universal Connection. It is such that*

$$a_{Amon}^N = \frac{Z + \delta(1 + \gamma)}{2} \quad q_A^N = q_j^N = \frac{Z + \delta(1 + \gamma)}{2t} \quad p_j^N = V'' \quad I_{Aj}^N = 1 \quad \forall j$$

Proof. See the Appendix. ■

Under Network Neutrality, Universal Connection is the unique equilibrium. Note that when both CPs are connected to the monopolist ISP, they cannot charge the monopoly price V' for ad slots. Hence, each CP would be better off if the rival were excluded. Yet, since connection is free, no CP is left out of the market.

4.3.2 Unregulated Regime

In the Unregulated Regime, ISP A charges a termination fee F_A to CPs, and CPs decide whether to connect. The following Proposition presents the subgame-perfect equilibria in this regime:

Proposition 2 *Suppose there is a monopolist ISP. In the Unregulated Regime:*

- if and only if the value of second ad impressions is high enough, i.e. $V'' \geq S_{mon}^U$, there exists a subgame-perfect equilibrium entailing Universal Connection. It is such that

$$F_A^U = V'' q_{mon}^{++} \quad a_A^U = \frac{Z + \delta(1 + \gamma)}{2} \quad q_A^U = q_j^U = q_{mon}^{++} = \frac{Z + \delta(1 + \gamma)}{2t} \quad p_j^U = V'' \quad I_{A_j}^U = 1 \quad \forall j$$

- if and only if the value of second ad impressions is low enough, i.e. $0 < V'' < S_{mon}^U$, there exists a subgame-perfect equilibrium entailing exclusion of one CP. It is such that

$$F_A^U = V' q_{mon}^+ \quad a_i^U = \frac{Z + \delta}{2} \quad q_A^U = q_j^U = q_{mon}^+ = \frac{Z + \delta}{2t} \quad p_j^U = V' \quad \sum_{j=0,1} I_{A_j}^U = 1 \quad \forall j$$

$$\text{where } S_{mon}^U \equiv \left(V' \left(\frac{Z + \delta}{2} \right) - \frac{\delta \gamma (2Z + 2\delta + \delta \gamma)}{2} \right) \frac{1}{Z + \delta(1 + \gamma)}.$$

Proof. See the Appendix. ■

The key difference between Network Neutrality and the Unregulated Regime is that in the latter the ISP can determine which network configuration will emerge using the termination fee. If ads lose little value when repeated (i.e. V'' is close enough to V'), CPs have a substantial willingness-to-pay for having their traffic terminated to consumers even if they have to compete for their attention. On top of this, high value of contents for consumers δ and complementarity γ induce the ISP to attract more CPs, since the loss of consumer base when excluding a content is significant. Hence, the ISP chooses a fee equal to V'' per consumer. By so doing, the ISP induces Universal Connection. The surplus extracted from each CP is relatively low, but the consumer base is maximized. Suppose instead that V'' is significantly lower than V' . The ISP uses the termination fee to exclude a CP. By setting a termination fee equal to V' per consumer reached, the ISP discourages one CP from connecting to its network. On the one hand, this fee extracts the high profits made by the CP that does connect (and enjoys a monopolist's position when selling "eyeballs" to advertisers). On the other hand, this termination fee also implies that the ISP renounces to a share of consumers (i.e. those who subscribe only if several contents are available).

4.4 Comparison of Network Neutrality and Unregulated Regime

Let us now briefly compare the two regulatory regimes. While all CPs are always distributed under Network Neutrality, one of them might be excluded in the Unregulated Regime. However, by itself, the removal of Network Neutrality is not sufficient to produce exclusion of content.

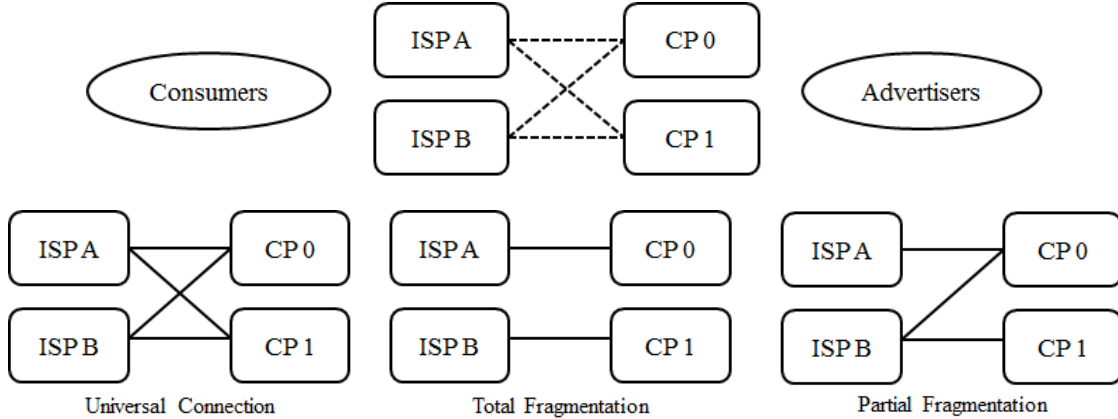


Figure 1: Duopoly setup and network configurations

Corollary 1 *Consider the monopoly case. If repeated impressions do not lose much value compared to first impressions (i.e. $V'' \geq S_{mon}^U$), Universal Connection is the unique equilibrium configuration, regardless of the regulatory regime. However, when the value of repeated ad impressions is sufficiently lower (i.e. $0 < V'' < S_{mon}^U$), the regulatory regime matters: Universal Connection is the unique equilibrium with Network Neutrality, while one CP is excluded in the Unregulated Regime.*

In welfare terms, consumers are always better off with Universal Connection than with exclusion, since they have access to more content. Gross surplus at both ends of the market is maximized with Universal Connection. It follows that total welfare is the highest under Universal Connection. We conclude that, in the simplified scenario we consider here, consumers and society as a whole are weakly better off under Network Neutrality than in the Unregulated Regime. We will provide a more thorough discussion of the welfare implications of the two regulatory regimes to the next section, where competition among ISPs is taken into account.

5 ISP duopoly

Let us now consider the fully-fledged version of the model, where both ISPs are active on the market. Figure 1 illustrates the setup and the main market configurations we will discuss below.

5.1 Stage 3

At stage 3, consumers choose which ISP they connect to, taking as given the CPs available at each ISP i and subscription fees a_i . We first determine the marginal consumer \bar{x} who is indifferent between the two ISPs. Equalizing $U_A(x) = U_B(x)$ and solving for x we find

$$\bar{x} = \frac{1}{2} + \frac{(\Delta_A - \Delta_B) - (a_A - a_B)}{2t}$$

The demand for ISP A is given by all consumers to the left of \bar{x} on the Hotelling line, while that for ISP B is given by all consumers to its right. That is, $q_A = \bar{x}$ and $q_B = 1 - \bar{x}$.

5.2 Stage 2

At stage 2, ISPs simultaneously set subscription fees, maximizing profits. They do so taking as given termination fees F_i as well as CPs' connection decisions (set at stage 1), and anticipating consumers' behavior (at stage 3). Equilibrium fees are obtained as the solution to the system of first order conditions $\frac{\partial \pi_i}{\partial a_i} = 0$ $i = A, B$. The result is

$$a_i^* = t + \frac{(\Delta_i - \Delta_{i'})}{3} \quad i = A, B \quad i' \neq i$$

Replacing a_i^* in q_i and π_i , we get equilibrium demands and profits²²

$$q_i^* = \frac{1}{2} + \frac{(\Delta_i - \Delta_{i'})}{6t} \quad \pi_i^* = \frac{(3t + \Delta_i - \Delta_{i'})^2}{18t} + \sum_{j=0,1} I_{ij} F_i \quad i = A, B \quad i' \neq i$$

Profits of platform i are increasing in $\Delta_i - \Delta_{i'}$. Hence, a uniform increase in quality of both platforms leaves profits unchanged.²³

In order to describe in a brief way the equilibrium demands conditional on the values of $\Delta_i - \Delta_{i'}$, we introduce some additional notation, summarized in Table 2.

²²We assume $\sum q_i^* = 1$ and $q_i^* > 0 \forall i$. This implies that $\delta(1 + \gamma) < 3t$ holds.

²³A remark is in order at this point. In a standard two-sided market framework, where ISPs decide simultaneously the fees for consumers and CPs, it may occur that ISPs cut subscription fees in order to attract more consumers and exploit network externalities on the content side. The timing we assume rules this out, since price competition for consumers comes at a later stage with respect to competition to attract contents. Hence, ISPs take revenues collected on the content side as given when deciding on subscription fees. We believe this to be a reasonable simplification, justified by the fact that contracts between ISPs and CPs have generally a more long-run perspective and their connection decision is more rigid than that between ISPs and consumers. A similar assumption is made by Choi, Jeon and Kim (2012) and Kourandi, Krämer and Valletti (2013).

$\Delta_i - \Delta_{i'}$	q_i^*	defined as	$\Delta_i - \Delta_{i'}$	q_i^*	defined as
$-\delta$	$\frac{1}{2} - \frac{\delta}{6t}$	q_i^{--}	δ	$\frac{1}{2} + \frac{\delta}{6t}$	q_i^{++}
$-\delta\gamma$	$\frac{1}{2} - \frac{\delta\gamma}{6t}$	q_i^-	$\delta\gamma$	$\frac{1}{2} + \frac{\delta\gamma}{6t}$	q_i^+
0	$\frac{1}{2}$		0	$\frac{1}{2}$	
$-\delta(1 + \gamma)$	$\frac{1}{2} - \frac{\delta(1+\gamma)}{6t}$	q_i^{---}	$\delta(1 + \gamma)$	$\frac{1}{2} + \frac{\delta(1+\gamma)}{6t}$	q_i^{+++}

Table 2: Notation for demand of ISP i , duopoly case.

CPs set prices for ad spaces in the same way as in the monopoly case described in Section 4. When advertisers can reach the same consumer through both CPs, competition drives down the per-impression price to V'' . When, instead, each CP is able to sell eyeballs to advertisers as a monopolist, the per-impression price is V' . Note that, differently from the monopoly case, we can now find situations where a CP is the unique gatekeeper only for a part of consumers connected to the Internet (the remaining part being reached also by the other CP). In this case, as we formally show in Lemma 3, the per-impression price for ad spaces of the CP connected to both ISPs is a weighted average of the value of first impression V' and second impression V'' . Lemma 3 presents CPs' profits at stage 2.

Lemma 3 *In equilibrium, advertisers multi-home on all CPs that have access to consumers. Profits π_j^* of CP $j=0,1$, conditional on the network configuration, are as reported in Table 3.*

π_0^*	π_1^*	$A\&B$	A	B	None
$A\&B$		$V'' - \sum F_i$ $V'' - \sum F_i$	$V''q^+ - F_A$ $V''q^+ + V'q^- - \sum F_i$	$V''q^+ - F_B$ $V''q^+ + V'q^- - \sum F_i$	0 $V' - \sum F_i$
A		$V''q^+ + V'q^- - \sum F_i$ $V''q^+ - F_A$	$V''q^{+++} - F_A$ $V''q^{+++} - F_A$	$\frac{V'}{2} - F_B$ $\frac{V'}{2} - F_A$	0 $V'q^{++} - F_A$
B		$V''q^+ + V'q^- - \sum F_i$ $V''q^+ - F_B$	$\frac{V'}{2} - F_A$ $\frac{V'}{2} - F_B$	$V''q^{+++} - F_B$ $V''q^{+++} - F_B$	0 $V'q^{++} - F_B$
None		$V' - \sum F_i$ 0	$V'q^{++} - F_A$ 0	$V'q^{++} - F_B$ 0	0 0

Table 3: Duopoly model: advertising profits π_j^* of CP j , conditionally on connection status.

Proof. See the Appendix. ■

5.3 Stage 1

At stage 1, ISP i sets the termination fee F_i and CPs decide which ISP to connect to, if any. Our objective is now to determine the subgame-perfect equilibrium of the game. We begin from the benchmark case of Network Neutrality. We consider the Unregulated Regime next.

5.3.1 Benchmark: Network Neutrality

In the Network Neutrality case, since $F_i = 0$, ISP profits are simply given by revenues collected from subscription fees

$$\pi_i^N = \frac{(3t + \Delta_i - \Delta_{-i})^2}{18t} \quad i = A, B$$

We now study CPs' connection choices. Elaborating from Table 3 in Lemma 3, we find

Proposition 3 *In the Network Neutrality regime:*

- *there always exists a subgame-perfect equilibrium entailing Universal Connection. It is such that*

$$a_i^N = t \quad q_i^N = \frac{1}{2} \quad p_j^N = V'' \quad q_j^N = 1 \quad I_{ij}^N = 1 \quad \forall i, j$$

- *if and only if the value of second impressions of advertisements is low enough, i.e. $V'' < S^N$, there also exists a subgame-perfect equilibrium entailing Total Fragmentation. It is such that*

$$a_i^N = t \quad q_i^N = \frac{1}{2} \quad p_j^N = V' \quad q_j^N = \frac{1}{2} \quad \sum_{j=0,1} I_{ij}^N = 1 \quad I_{ij}^N \neq I_{-ij}^N \quad \forall i, j$$

where $S^N \equiv V' \left(\frac{\delta\gamma}{3t+\delta\gamma} \right)$.

Proof. See the Appendix. ■

Proposition 3 provides us with a first important result: with Network Neutrality, Universal Connection is always an equilibrium, even though it is not necessarily the most profitable for CPs. When connecting to the same ISP, each CP produces a strategic externality on its rival, eliminating the possibility to charge the monopolistic price V' for ad slots. It follows that, when the price of ad spaces is strongly reduced by competition (i.e. V'' is significantly smaller than V'), CPs could make higher profits if each had its content distributed by a different ISP. Yet, since with a zero-price rule in place consumers can be freely reached, Universal Connection is always an equilibrium. In other words, CPs find themselves in a prisoner's dilemma, to the benefit of consumers (who enjoy more choice of content) and advertisers (who get to pay a competitive price for placing their ads).

The first result in Proposition 3 confirms the intuition that a zero-price rule may help prevent fragmentation and preserve universal content availability on the Internet. Nevertheless, Network Neutrality is not sufficient to guarantee Universal Connection. There also exists the possibility of a second equilibrium, characterized by Total Fragmentation. This occurs when competition among CPs strongly affects their profitability and/or contents are highly valuable to consumers and complementary. Indeed, the threshold S^N reported in Proposition 3 is strictly increasing in δ and γ . Hence, if ad impressions rapidly lose value when repeated and content is important for consumers, Total Fragmentation can occur even with Network Neutrality regulation in place.

The last finding is quite counterintuitive: one may, a priori, expect that if contents are highly complementary and important for consumers, each CP would have a strong incentive to deviate from the fragmentation equilibrium. After all, if the CP is strongly attractive for consumers, it can largely increase its audience by connecting to an additional ISP. To see

why it is not the case, suppose that CP 0 is connected to ISP A and CP 1 to B . Suppose 0 has to decide whether to connect also to ISP B or not. If it does not connect to B , the price it can charge for ad spaces is V' , given that it is the only outlet for advertisers wanting to reach A 's consumers. If CP 0 connects to B as well, its consumer base is enlarged, including also B 's customers. Nevertheless, the price it can charge for ad spaces is now the weighted average $V'q^- + V''q^+$. This is because part of its audience (i.e. B 's customers) would already be reached by the rival. Moreover, CP 0 increases B 's attractiveness for consumers relative to A . Hence, though connection is free, it has an implicit cost: the quantity of eyeballs CP 0 monopolizes shrinks, since some consumers migrate from one ISP to the other. The share of "migrating" consumers is particularly relevant when contents are valuable and highly complementary. Thus, the CP may prefer not to connect to the additional ISP, even if it can do so for free.

Summing up, our results suggest that, in the Network Neutrality regime, Universal Connection is always an equilibrium, though not the only one when competition among CPs strongly impacts their profitability. In that case, Total Fragmentation is also possible.

5.3.2 Unregulated Regime

We now study the Unregulated Regime. At stage 1, ISPs decide the termination fees F_i and CPs choose to which ISP they connect. When deciding their fees, ISPs anticipate the profits they will make at the following stages. A couple of fees (F_A, F_B) is an equilibrium if no ISP wants to deviate and if CPs are willing to pay them. The network configuration that arises at equilibrium is the consequence of ISPs' and CPs' decisions. Hence, it is induced by the couple (F_A, F_B) . The equilibrium are described in Proposition 4.

Proposition 4 *In the Unregulated Regime:*

- if and only if the value of second ad impressions is low enough, i.e. $0 \leq V'' < S_{TF}^U$, there exists a subgame-perfect equilibrium entailing Total Fragmentation. It is such that:

$$F_i^U = \frac{V'}{2} \quad a_i^U = t \quad q_i^U = \frac{1}{2} \quad p_j^U = V' \quad q_j^U = \frac{1}{2} \quad \sum_{j=0,1} I_{ij}^U = 1 \quad I_{ij}^U \neq I_{-ij}^U \quad \forall i, j$$

$$\text{where } S_{TF}^U \equiv \left(\frac{V'}{2} + \frac{t}{2} - \frac{(3t+\delta(1+\gamma))^2}{18t} \right) \left(\frac{3t}{3t+\delta(1+\gamma)} \right)$$

- if and only if the value of second ad impressions is high enough, i.e. $S_{UC}^U \leq V'' \leq V'$, there exists a subgame-perfect equilibrium entailing Universal Connection. It is such

that:

$$F_i^U = V'' q^- \quad a_i^U = t \quad q_i^U = \frac{1}{2} \quad p_j^U = V'' \quad q_j^U = 1 \quad I_{ij}^U = 1 \quad \forall i, j$$

where $S_{UC}^U \equiv V' \left(\frac{3t}{6t+\delta} \right)$. Note that $S_{UC}^U > S_{TF}^U$.

Proof. See the Appendix. ■

The results in Proposition 4 indicate that adopting a regulatory regime that allows for termination fees may affect the configuration of the network. First of all, when $0 \leq V'' < S_{TF}^U$ the equilibrium necessarily entails Total Fragmentation. When competition among CPs strongly decreases ad rates (i.e. V'' is low with respect to V') and/or content is of little relevance for consumers (i.e. δ is small) and/or highly substitutable (i.e. γ is small), ISPs avoid competition to attract CPs and set a high termination fee $\frac{V'}{2}$. This fee is equal to the profit the CP makes by selling exclusive ad impressions on a consumer, V' , multiplied by the number of consumers that subscribe to the ISP, i.e. $\frac{1}{2}$. A CP is willing to pay such a fee if and only if it can charge V' per impression, i.e. if there is no competition to attract advertisers. Consequently, this high fee induces network fragmentation. To see why Total Fragmentation emerges at equilibrium only when the value of second ad impressions is sufficiently low, consider that the most profitable deviation from this equilibrium for an ISP (say, A) is to charge a fee equal to $V'' q^{+++}$. Assuming B sticks to $F_B = \frac{V'}{2}$, both CPs join only A . By so doing, ISP A becomes more attractive than the rival in the eyes of consumers. However, when V'' , δ and γ are small, the cost of this deviation on the content side (a lower termination fee) outweighs the gains on the consumer side (a greater number of subscribers). It follows that no ISP deviates. As a result, the network is fragmented at equilibrium. Observe, indeed, that threshold S_{TF}^U is decreasing in both γ and δ .

Universal Connection is nevertheless not always ruled out in the Unregulated Regime. When $S_{UC}^U \leq V'' \leq V'$, competition among CPs brings a relatively small decrease in ad rates (i.e. V'' is high enough with respect to V') and/or availability of content is relevant for consumers (i.e. δ is large). Our results suggest that, in that case, ISPs compete to attract CPs, setting a low termination fee $V'' q^-$. As a result, Universal Connection arises at equilibrium.²⁴ The most profitable deviation from the Universal Connection equilibrium for ISP i is to raise the fee to a level high enough to induce Total Fragmentation. By so doing, the ISP gives up on revenues from one CP, capturing at the same time extra profits from the remaining one. However, when V'' and δ are high, the extra profits are simply too small to make such a deviation unilaterally profitable.

²⁴If V'' is strictly larger than S_{UC}^U , other equilibria entailing Universal Connection may arise in which both ISPs set fees below $V'' q^-$. We do not elaborate on such equilibria since their nature is essentially the same as the one described in Proposition 4. The only difference is that competition may drive termination fees even below the level presented in the Proposition, while all other prices and quantities are invariant.

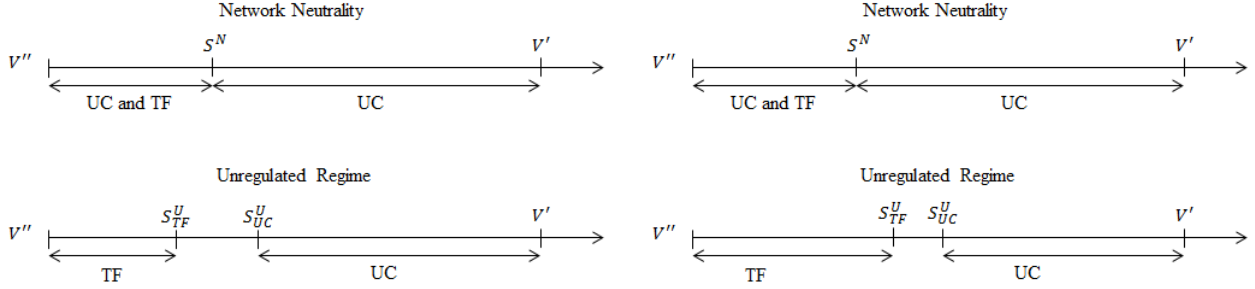


Figure 2: Representation of the pure-strategy equilibria in the two regulatory regimes. On the left we have case $S_{TF}^U \leq S^N$ and on the right case $S_{TF}^U > S^N$. UC stands for “Universal Connection” and TF for “Total Fragmentation”.

Finally, Proposition 4 suggests that in the Unregulated Regime only Universal Connection and Total Fragmentation can arise in a pure-strategy equilibrium. There is no pure-strategy equilibrium involving Partial Fragmentation. It turns out that there is always a profitable deviation from such a configuration, for at least one ISP. Take, for example, the case where CP 0 connects only to ISP A and CP 1 to both A and B . Two situations are possible. In the first, the values of repeated ad impressions and content attractiveness are high enough that B (i.e. the ISP with only one CP) prefers to lower its tariff in order to try to have both CPs on board. In the other, those values are low enough that A (i.e. the ISP signing up two CPs) is better off excluding one of them.

Furthermore, Universal Connection and Total Fragmentation can only arise in mutually exclusive regions. Indeed, $S_{TF}^U < S_{UC}^U$. As a final remark, note that when $S_{TF}^U < V'' < S_{UC}^U$, no pure-strategy equilibrium exists. Unfortunately, the analysis of mixed strategy equilibria turns out to be quite complex in our framework. Hence, we will forgo it in order to avoid making the presentation of the results excessively involved.

5.4 Comparison of Network Neutrality and Unregulated Regime

5.4.1 Network configurations

We now proceed to a comparison of the two regulatory regimes and describe how the introduction of termination fees may influence the configuration of the Internet. Figure 2 provides a graphical representation of the pure-strategy equilibria.

To begin, our results suggest that Universal Connection is less likely in the Unregulated Regime than with Network Neutrality. It is easily shown that $S^N < S_{UC}^U$. Hence, Propositions 3 and 4 imply that conditions for Universal Connection to be the unique pure-strategy equilibrium are always weaker with Network Neutrality than in its absence. Moreover, Universal

Connection is always an equilibrium with Network Neutrality. In contrast, it is ruled out in the Unregulated Regime when $S_{TF}^U > V''$, that is, when repeated ad impressions lose much value compared to a first impression and/or content is not highly valuable for consumers.

Our results also suggest that a change in the regulatory regime does not necessarily imply a change in network configuration. Indeed, when $S_{UC}^U \leq V''$, Universal Connection is the only equilibrium in both regulatory regimes. Moreover, Total Fragmentation can take place even if Network Neutrality is maintained. This is the case when competition among CPs strongly reduces their profitability as advertising outlets, i.e. when $V'' < S_{TF}^U$. Nonetheless, in that case, Total Fragmentation is the unique equilibrium in the Unregulated Regime, but not with Network Neutrality.

These results highlight the importance of termination fees as strategic variables affecting the network configuration and, in turn, the online advertising market. When consumers have weak valuation for contents and the value of repeated ad impressions is low, each CP could make higher profits by fragmenting the market. This is because competing to attract advertisers strongly reduces their profitability. Yet, in the Network Neutrality regime, CPs may not be able to coordinate on a fragmentation equilibrium and thus escape competition. If the Unregulated Regime is adopted, however, termination fees act as the missing coordination device. As a consequence, contrarily to the Network Neutrality regime, Total Fragmentation is the unique equilibrium.

Summing up, the results suggest that, on the one hand, Network Neutrality certainly helps preserving universal access to online content. On the other hand, the extent to which repeated ad impressions lose value is crucial in shaping the network configuration, regardless of the regulatory regime. We summarize our main conclusions in the following²⁵

Corollary 2

- *Conditions ensuring that Universal Connection is the unique pure-strategy equilibrium are weaker with Network Neutrality regulation than in the Unregulated Regime. Moreover, if Network Neutrality is enforced, Universal Connection is always an equilibrium*

²⁵The reader will perhaps note that the comparison among the two regimes in the Corollary is only piecemeal: we restrict attention to the intervals where a pure-strategy equilibrium exists in both regimes. If (and only if) $S_{TF}^U < V'' < S_{UC}^U$, no pure strategy equilibrium exists in the Unregulated Regime. Nevertheless, if parameter values are such that $S_{TF}^U \geq S^N$, when $S_{TF}^U < V'' < S_{UC}^U$ Universal Connection is the unique pure strategy equilibrium with Net Neutrality. Therefore, one can conclude that in $S_{TF}^U < V'' < S_{UC}^U$ Universal Connection emerges always at least as frequently with Network Neutrality as in the Unregulated Regime (see Figure 2) and all results in Corollary 2 are confirmed. If parameter values are such that $S_{TF}^U < S^N$, then when $S_{TF}^U < V'' < S^N$ Universal Connection and Total Fragmentation are both equilibria with Network Neutrality. However, Universal Connection could occur in mixed-strategies in the Unregulated Regime. Hence, the comparison among the two regimes is less straightforward.

(though not necessarily unique). This is not true in the Unregulated Regime.

- If the value of repeated ad impressions is low enough, the regulatory regime influences the network configuration. First, when $0 \leq V'' < \min \{S^N; S_{TF}^U\}$ both Total Fragmentation and Universal Connection are equilibria with Network Neutrality, but only Total Fragmentation is an equilibrium in the Unregulated Regime. Second, when $S^N \leq V'' < S_{TF}^U$ Universal Connection is the unique equilibrium with Network Neutrality and Total Fragmentation is the unique equilibrium in the Unregulated Regime. However, if repeated impressions do not lose much value compared to first impressions (i.e. $S_{UC}^U \leq V''$) Universal Connection is the unique equilibrium regardless of the regulatory regime.

The role of content availability and complementarity. Propositions 3 and 4 also provide interesting insights on the role played by content value and complementarity in shaping network configurations. Interestingly, the extent to which these affect the likelihood of fragmentation changes with the regulatory regime. First of all, with Network Neutrality both the absolute valuation for content δ and complementarity γ increase chances for fragmentation. In contrast, in the Unregulated Regime, consumer valuation for content makes Universal Connection more likely (though content complementarity is irrelevant). Furthermore, in the Unregulated Regime δ and γ play a more intuitive role, as they reduce the likelihood of Total Fragmentation.

5.4.2 The effect on consumer surplus, profits and welfare

We now turn to a welfare comparison of the regulatory regimes. The equilibrium entailing Universal Connection is always optimal for consumers. Compared to Total Fragmentation, they end up paying the same subscription fee (i.e. $a = t$), but enjoy a larger choice of contents. Indeed, consumer surplus is $Z + \delta(1 + \gamma) - \frac{5}{4}t$ under Universal Connection and $Z + \delta - \frac{5}{4}t$ with Total Fragmentation. Consumers are thus indifferent between Network Neutrality and the Unregulated Regime when the value of second ad impressions is sufficiently high (i.e. $S_{UC}^U < V''$), as Universal Connection is the equilibrium configuration in both regimes. When first ad impressions are much more valuable than repeated ones (i.e. $V'' \leq S_{TF}^U$), instead, switching from Network Neutrality to the Unregulated Regime means that Universal Connection is unattainable. Hence, in that case consumers are (weakly) better off with Network Neutrality than with the Unregulated Regime.²⁶

²⁶Once again, we focus our attention on pure-strategy equilibria in both regimes. When $S_{TF}^U < V'' < S_{UC}^U$ and $S_{TF}^U \geq S^N$, consumers are at least as well off with Network Neutrality as in the Unregulated Regime. This is because Universal Connection is the unique equilibrium in the former. Hence, regardless of which (mixed-strategy) equilibrium emerges in the latter, consumers cannot be better off. The comparison is less

Let us now consider advertisers. In the Total Fragmentation case, CPs can charge monopoly prices for ad spaces, extracting all advertiser surplus. Instead, advertisers retain some profits under Universal Connection. Advertiser surplus is equal to zero under Total Fragmentation and to $V' - V''$ under Universal Connection. Therefore, like consumers, advertisers are (weakly) better off with Network Neutrality when $V'' \leq S_{TF}^U$ and indifferent to the regulatory regime when $S_{UC}^U < V''$.²⁷

Considering now ISPs and CPs, a switch from the Network Neutrality to the Unregulated Regime always penalizes the latter while benefiting the former. This is true regardless of whether changes in the regulatory regime modify the market configuration or not. Under the Unregulated Regime, ISPs obtain extra profits from termination fees paid by CPs. Moreover, ISPs see no change in profits on the consumer side of the market, since all equilibria are symmetric and total subscription fees collected are invariant. Thus, abandoning the Network Neutrality regime always entails a transfer of profits from CPs to ISPs. Indeed, the profit of an ISP is $\pi_i^N = \frac{t}{2}$ with Network Neutrality independently of the configuration of the network. In the Unregulated Regime, an ISP obtains $\pi_i^U = \frac{t}{2} + 2V''q^-$ with Universal Connection and $\pi_i^U = \frac{t}{2} + \frac{V'}{2}$ with Total Fragmentation. As for CPs, each makes $\pi_j^N = V''$ with Universal Connection and $\pi_j^N = \frac{V'}{2}$ with Total Fragmentation under Network Neutrality, while it gains, respectively, $\pi_j^U = V'' - 2V''q^-$ and $\pi_j^U = 0$ in the Unregulated Regime.

Let us finally look at the change in social welfare. As stated in Lemma 1, Universal Connection is the optimal configuration from a social welfare point of view. Hence, Network Neutrality is the (weakly) optimal regulatory regime when repeated ad impressions rapidly lose value *i.e.* $V'' < S_{TF}^U$. The two regimes are instead equivalent when $S_{UC}^U \leq V''$. Summing up, we conclude the following

Proposition 5 *If the value of repeated ad impressions is low enough, *i.e.* $V'' < S_{TF}^U$, consumer, advertiser and social welfare are weakly higher under Network Neutrality than in the Unregulated Regime. However, if repeated impressions do not lose much value compared to first impressions (*i.e.* $S_{UC}^U \leq V''$), consumer, advertiser and social welfare are unaffected by a change in regulatory regime. Finally, ISPs are always better off and CPs always worse off under the Unregulated Regime than under Network Neutrality.*

Proof. The results follow from Proposition 3 and 4 and the discussion in the text. ■

clear-cut when $S_{TF}^U < V'' < S^N$, since we have a multiplicity of equilibria with Network Neutrality. It is therefore difficult to establish which regulatory regime would make consumers better off.

²⁷In our model the value of a first ad impression does not depend on whether a consumer visits one or more contents. Alternatively, one could assume that it decreases in the number of available contents, for instance because the consumer spends less time on a single content. With respect to our formulation, taking this fact into account would increase the gross surplus on the advertising side with Total Fragmentation and thus raise its social desirability.

6 Robustness of the results

Before proceeding to the policy implications of our work, the reader should note that we have so far focused on the relation between termination fees and network fragmentation, in order to isolate some of the forces determining the latter. A thorough analysis of the implications of Network Neutrality regulation would have to account for several other forces and it is difficult to include them all in a tractable model. In this Section we discuss some aspects of the Network Neutrality policy debate that have been left out of our formal analysis.

Congestion and priority fees. Opponents of Network Neutrality regulation argue that allowing ISPs to practice service tiering and priority fees could alleviate traffic congestion. Modeling them would certainly make the analysis richer. However, we believe this would not change our basic findings concerning Internet fragmentation. When Network Neutrality is enforced, congestion would not reduce the incentives for CPs to connect to both ISPs. To see why, consider the Universal Connection equilibrium: if a CP were to abandon an ISP, this would most likely not affect the level of congestion on the ISP to which it is connected. Hence, no additional gain could be expected from connecting to just one ISP rather than to both. In the Unregulated Regime, ISPs could (conditionally on the payment of a fee) grant priority to some traffic while reducing the quality of service for the rest. It is therefore conceivable that the CPs which do not acquire priority from a given ISP would become much less attractive for consumers, losing appeal as an advertising outlet. On the contrary, the CPs who acquire priority could command much greater prices when setting ad rates than their non-prioritized rivals. As long as competition among CPs strongly reduces ad rates, CPs may find it rational to acquire priority at different ISPs, leading *de facto* to a fragmented Internet. Thus, although subscribers to one ISP could in principle browse both contents, the end result would be that consumers connecting to one ISP would be strongly encouraged to browse just the prioritized CP, while those connecting to the rival ISP would be encouraged to browse only the other. Of course, when congestion is taken into account, an ISP that uses priority fees could be more efficient in delivering content to consumers. This would increase the desirability of the Unregulated Regime if congestion is strong and service tiering alleviates it.

Multiple CPs. In our model only two CPs are available. Of course, in reality, consumers generally browse more than two contents. One may therefore wonder how our main results would change if several CPs were modeled. Suppose we had $N > 2$ CPs. As long as consumers browse more than one and audiences overlap, CPs would still compete on ad rates

in order to attract multi-homing advertisers. In fact, if consumers browse more than two CPs, competition on the advertising market would, in all likelihood, be even stronger. This follows from the fact that the more CPs consumers browse, the greater the chances they will be exposed to a given ad multiple times. Thus, ISPs may find it even more rational to raise termination fees, possibly leading not only fragmentation but also to exclusion of some CPs from the market. This suggests that the main forces driving our results would not change.

Disutility from advertisements. A further aspect that has so far been disregarded is that consumers may suffer some disutility from advertisements. Although advertising avoidance and targeting technologies are widespread, ads are generally a nuisance for consumers. Nevertheless, we do not expect that introducing such disutility would radically change our analysis. In our model consumers visit all available contents. The marginal utility of browsing a content depends on the number of available contents and the degree of complementarity (parameters δ and γ). Moreover, in equilibrium, advertisers multi-home: the quantity of ads is thus invariant with the network configuration. With fragmentation, each ad reaches a given consumer only once. With universal connection, each consumer is exposed to the same ad twice. However, the number of ad impressions per content visited is constant. Thus, any nuisance from advertisements can simply be incorporated in the model as an additional term in individual utility, in the same way as parameters δ and γ . These can therefore be interpreted as the marginal utility of content availability *net of ad nuisance costs*. As long as the latter is positive (which seems reasonable), our analysis would not change. Of course, disutility from ads would mean that the value of content availability for consumers would be reduced with respect to a no-nuisance scenario. However, the results in Proposition 5 would still be valid.

Note also that more detailed models of platform competition for online advertisers (that explicitly account for nuisance costs) get to similar conclusions to ours. For example, Ambrus, Calvano and Reisinger (2013) study the effects of platform (i.e. content) competition in advertising markets when both consumers and advertisers multi-home. They include disutility from ads in the model and assume that consumers decide which content to join before platforms sell advertising space. This timing is important for their results. One of their main conclusions is that the quantity of ads platforms carry is invariant with the extent of competition among platforms. This is in line with what we find.

Investment in network infrastructure and content quality. Our analysis has also abstracted from investment in infrastructure by ISPs, as well as in content quality by CPs. It is conceivable that these may be affected by the regulatory regime. It follows that considering

investment may, a priori, change the welfare comparison between the two regimes (Proposition 5). Unfortunately, adding an investment stage to the model would make a formal analysis much harder to treat. This is because the marginal benefit of investment for both ISPs and CPs depends on which network configuration arises at equilibrium. Since profits are non-continuous functions of investment and fees (they change discontinuously with the network configuration), it is difficult to characterize the equilibrium investment quantities. We can nonetheless try to speculate on what would happen if investment were endogenized using a slightly simplified setup.

Begin by considering investment in network infrastructure by ISPs. Suppose that we added a preliminary stage to the model in which ISPs simultaneously invest in infrastructure. The resulting quality of service offered by ISP can be captured by a parameter Z_i in consumer utility. We assume that investment in Z_i entails a quadratic cost, i.e. $\frac{Z_i^2}{2}$. ISPs choose Z_i maximising profits, taking the choice of the rival as given. To simplify, assume that the equilibrium at the investment stage is symmetric, i.e. such that $Z_A = Z_B$. This implies that equilibrium quantities and prices are the same as in Proposition 3 and 4. With Network Neutrality regulation in place, the equilibrium level of investment would be $Z_{UC}^N = Z_{TF}^N = \frac{1}{3}$, irrespectively of whether the network configuration is Universal Connection or Total Fragmentation. This is because when termination fees are restricted to zero, ISPs make profits only from selling consumer subscriptions. Since network configurations are symmetric, the marginal change in profits with respect to Z_i is invariant with the equilibrium configuration. In the Unregulated Regime, ISPs choose $Z_{UC}^U = \frac{1}{3} + \frac{V''}{3t}$ and $Z_{TF}^U = \frac{1}{3} + \frac{V'}{6t}$ when, respectively, Universal Connection and Total Fragmentation occur. It is therefore easy to verify that investment is higher under the Unregulated Regime than under Network Neutrality. This is because ISPs anticipate that greater infrastructure quality will increase both the profit made on the consumer side and termination fees collected from content providers.

Let us now try to appraise the impact of infrastructure investment on the welfare comparison between the two regimes. Suppose the network configuration is not affected by a change in the regulatory regime. Endogenizing investment by ISPs would make the Unregulated Regime strictly preferable to Network Neutrality. This is because content accessibility would be unaffected, but infrastructure quality strictly improved. However, if the network configuration is sensitive to a change in the regulatory regime (see Corollary 2), the regulator may be faced with a trade-off: the Unregulated Regime may bring to higher investments in infrastructure, but also to a fragmented Internet. Which regime is more desirable? Suppose parameter values were such that Universal Connection occurs with Network Neutrality and Total Fragmentation emerges in the Unregulated Regime. We would expect welfare to be higher under the Unregulated Regime than under Network Neutrality if content is not impor-

tant for consumers and if the value of first impressions of ads is high enough. This is because, with Total Fragmentation, the termination fee is proportional to V' and to the number of subscribers to the ISP (see Proposition 4). Thus, the larger V' , the greater the marginal benefit of increasing the consumer base through better infrastructure quality. Greater investment thus outweighs the welfare loss of reduced content availability if content variety is not highly valued by consumers.

Let us now consider investment in content quality by CPs. Our model is not well suited to study this question, since consumers' demands for CPs are inelastic with respect to content quality. Hence, CPs would have no incentives to invest. In a more general model, however, we would expect the Network Neutrality regime to favor investment by CPs: this is because higher content attractiveness allows them to retain a larger share of profits made selling ad spaces. Summing up, in a general model where investment by both ISPs and by CPs is endogenized, Network Neutrality should favor the latter, while the Unregulated Regime should favor the former. Hence, it is not clear that considering investment would reverse our ranking of regulatory regimes in terms of consumer surplus and overall welfare.

7 Policy Implications

We now discuss some policy implications of our results. Proposition 5 suggests that policymakers should aim to preserve Universal Connection, regardless of whether their main concern is consumer surplus or overall welfare. We have seen that when competition among CPs has a relevant impact on advertising rates, having CPs pay termination fees (even if strictly non-discriminatory) may rule out Universal Connection. Consequently, in that case a regulator should be wary of allowing such fees. However, our formal model has some limitations. To begin, we did not consider congestion. In its presence, priority fees could bring to a more efficient use of the spectrum (though they may still favor Internet fragmentation, see Section 6 above). Perhaps more importantly, in the long run, termination fees may foster infrastructure investment by ISPs. Therefore we cannot conclude that such fees should be ruled out. Our results suggest, nonetheless, that it may be difficult for a regulator to at the same time prevent fragmentation and ensure efficient network management by granting ISPs more flexibility in setting fees.

If a regulator intends to prevent Internet fragmentation, it could make it mandatory for ISPs to terminate all traffic directed to their subscribers (without discrimination). Yet, CPs may simply prefer not to ask for termination of their traffic if faced with too high fees. For these reasons, when the social costs of fragmentation are large, the regulator may still have to intervene by capping termination or priority fees to a low enough level (or banning them

outright).²⁸ On the contrary, there may be cases in which even imposing a zero-price rule does not prevent fragmentation (see Proposition 3): if this is the objective, the regulator may have to impose stricter regulation, making connection mandatory.

Our results also suggest that introducing termination fees does not systematically lead to fragmentation (Propositions 3 and 4). When competition among CPs has little impact on advertising rates, Universal Connection emerges in equilibrium regardless. Thus, in that case, a regulator should be less worried about the risk of fragmentation, especially if termination fees allow a more efficient use of bandwidth and boost infrastructure investment.

8 Conclusions

We have investigated the implications of Network Neutrality regulation (intended as a zero-price rule for CPs) for fragmentation of the Internet. Our analysis has highlighted an important link between fragmentation and the advertising market. We have shown that, without a zero-price rule, ISPs may use non-discriminatory termination fees to rule out Universal Connection and allow CPs to impose monopoly prices for ads. However, abandoning Network Neutrality does not necessarily imply changes in network configuration. Yet, since both social welfare and consumer surplus are maximized with Universal Connection, the Unregulated Regime is weakly dominated by Network Neutrality.

It is obviously hard to capture in a single model all the forces that may shape the configuration of the Internet. Nonetheless, we believe our findings to be an interesting addition to the rapidly-growing literature on the topic. As we discussed in Section 6, the main issues we ignored would in all likelihood dilute but not reverse the effects we identified. Of course, many interesting issues remain to be investigated. Some of these have been discussed above, but it would be interesting to extend our analysis to explore their implications in a more rigorous way. This is in particular the case for investment by ISPs and CPs. Moreover, it would be interesting to study other forces that could induce fragmentation, such as the presence of vertically integrated ISPs. In this case, ISPs may have an incentive to insulate and protect the affiliated content from competition, and they could use termination fees with this objective. A formal treatment of this important issue would be an interesting step for future research.

²⁸For further discussion on the reasons why zero termination fees should be preferred to positive ones see Lee and Wu (2009).

Appendix

Proof of Lemma 2

Notation. In order to describe in a concise way the network configurations that may arise in equilibrium, we now introduce some notation. In the following, network configuration $(0A, 1A)$ means that both 0 and 1 connect to A (i.e. $I_{Aj} = 1 \forall j$): we refer to this configuration (in the monopoly scenario) as “Universal Connection”; $(0A, 1N)$ means that 0 connects to A and 1 connects to no ISP (i.e. $I_{A0} = 1 \ I_{A1} = 0$); $(0N, 1N)$ means that no CP connects to any ISP.

We consider each possible market configuration in turn. Consider first the Universal Connection case. Thus, an advertiser can reach all viewers from both CP, i.e. $q_j = q_A = q_{mon}^{++} \ j = 0, 1$. Suppose an advertiser puts ads on both CPs. Its total surplus would be $(V' + V'' - \sum_{j=0,1} p_j) q_{mon}^{++}$. Suppose instead the advertiser decides to put ads only on CP j . Its total surplus is since, in this case, consumers are exposed only to first impressions. This implies that an advertiser prefers to put ads on both CPs rather than on one if and only if $(V' + V'' - \sum_{j=0,1} p_j) q_{mon}^{++} > (V' - p_j) q_{mon}^{++}$, i.e. $V'' \geq p_j$. We now prove that $p_j = V'' \ j = 0, 1$ is the equilibrium price schedule for advertising spaces and that advertisers multi-home. Suppose $p_{j'} \leq V''$: as long as $p_j \leq V''$ advertisers would optimally multi-home and put ads on both CPs, while if $p_j > V''$ no platform would join CP j . Hence, it is optimal for CP j to set $p_j = V''$. Suppose instead that $p_{j'} > V''$: then, it is optimal for j to set $p_j = p_{j'} - \varepsilon$. By so doing, all advertisers would single-home and buy only ad slots from j , leaving the other CP with zero revenues. It follows that the only equilibrium prices (mutual best response) are such that $p_j = V'' \ j = 0, 1$. It is easily seen that, in such equilibrium, all advertisers multi-home. Hence, each CP makes a profit equal to $V'' q_{mon}^{++} - F_A$.

Suppose now the market configuration involves exclusion, i.e. either $(0A, 1N)$ or $(0N, 1A)$. For instance, consider configuration $(0A, 1N)$. The advertiser can reach through CP 0 $q_0 = q_A = q_{mon}^+$ consumers and no consumers through CP 1. If an advertiser puts ads on both CPs, its total surplus is $(V' - \sum_{j=0,1} p_j) q_{mon}^+$. If ads are put only on CP 0, the surplus is $(V' - p_0) q_{mon}^+$. If instead ads are put only on CP 1, the surplus is $0 - p_1$. We now prove that CPs set the following equilibrium prices: $p_1 = 0$ and $p_0 = V'$. Indeed, as CP 1 does not provide any surplus to advertisers (since it is not able to reach consumers), they never join its platform for any positive price. Instead, CP 0 has no incentive to fix any price lower than V' , since advertisers join its platform for a price lower or equal to this value. Hence, CP 1's profits are $\pi_1 = 0$ and CP 0's profits are $\pi_0 = V' q_{mon}^+ - F_A$.

Trivially, when no CP is connected, no advertising takes place. Hence, all profits are zero.

Proof of Proposition 1

Looking at the table provided in Lemma 1, we have

1. Configuration (0A,1A) obtains when

$$F_A \leq V'' q_{mon}^{++}$$

2. (0A,1N) or (0N,1A)

$$V'' q_{mon}^{++} < F_A \leq V' q_{mon}^+$$

3. (0N,1N)

$$F_A > V' q_{mon}^+$$

Setting now all $F_i = 0$, one easily verifies that only the equilibrium described in the claim exists.

Proof of Proposition 2

ISP A can choose whether to provide access to both CPs or only to one CP. Clearly, providing access to no CP is always a dominated choice. If it provides access to both CPs, ISP A will set the highest termination fee CPs are willing to pay when both reach the same consumers, i.e. $F_A = V'' q_{mon}^{++}$. In this case, ISP's A profits are $\pi_A = 2V'' q_{mon}^{++} + \frac{(Z+\delta(1+\gamma))^2}{4t}$. If A provides access only to one CP, it will set the highest fee a CP is willing to pay given that it has exclusive access to consumers, i.e. $F_A = V' q_{mon}^+$.²⁹ In this case, ISP's A profits are $\pi_A = V' q_{mon}^+ + \frac{(Z+\delta)^2}{4t}$. Hence, ISP A sets $F_A = V'' q_{mon}^{++}$ and induces the network configuration (0A,1A) if and only if $2V'' q_{mon}^{++} + \frac{(Z+\delta(1+\gamma))^2}{4t} \geq V' q_{mon}^+ + \frac{(Z+\delta)^2}{4t}$. That is, by simple algebra, if and only if

$$V'' \geq \left(V' \left(\frac{Z + \delta}{2} \right) - \frac{\delta\gamma(2\delta + 2Z + \delta\gamma)}{4} \right) \left(\frac{1}{Z + \delta(1 + \gamma)} \right)$$

Otherwise, it sets $F_A = V' q_{mon}^+$ and induces the network configuration $(jA, j'N)$, with $j, j' \in \{0, 1\}$ $0 \neq 1$.

Proof of Lemma 3

Notation. Following the notation introduced above, network configuration (0AB,1AB) will here mean that 0 connects to both A and B and 1 connects to both A and B (i.e.

²⁹The configurations (0A,1N) or (0N,1A) can take place if $V'' q_{mon}^{++} < V' q_{mon}^+$.

$I_{ij} = 1 \forall i, j$): in the text, we refer to this configuration as “Universal Connection”. $(0A, 1B)$ means that 0 connects only to A and so does 1 (i.e. $I_{A0} = I_{B1} = 1$ $I_{A1} = I_{B0} = 0$): in the text, we refer to this configuration, where each ISP provides exclusive access to a single (different) CP, as “Total Fragmentation”. $(0A, 1AB)$ means that 0 connects to ISP A and 1 connects to both: in the text, we refer to this configuration, where a CP joins only one ISP, while the other CP joins both ISPs as “Partial Fragmentation”. Finally, $(0N, 1AB)$ means that 0 connects to no ISP and 1 connects to both A and B , ($I_{A1} = I_{B1} = 1$ $I_{A0} = I_{B0} = 0$). Similar notation is used for all other configurations.

We consider each of the possible market configurations in turn.

Market configuration $(0AB, 1AB)$. First, consider Universal Connection. If an advertiser puts ads on both CPs, its total surplus would be $V' + V'' - p_0 - p_1$. If instead ads are put only on CP i , the surplus is $V' - p_i$. The discussion concerning this configuration is the same as the one in the proof of Lemma 2 for configuration $(0A, 1A)$.

Market configuration $(0i, 1i')$, with $i, i' \in \{A, B\}$ and $i \neq i'$. Suppose now the market configuration involves partial fragmentation. For instance, consider the case $(0AB, 1A)$. If an advertiser puts ads on both CPs, its surplus would be $(V' - p_0)q^- + (V' + V'' - p_0 - p_1)q^+$, since there are q^- exclusive consumers and q^+ non-exclusive consumers. If instead ads are put only on CP 0, the surplus is $V' - p_0$, since all consumers are reached exclusively. Finally, if ads are put only on CP 1, its surplus is $(V' - p_1)q^+$, since only q^+ are impressed once by the ad. We now prove that ISPs set the following equilibrium prices: $p_1 = V''$ and $p_0 = V'q^- + V''q^+$ and that advertisers multi-home. Let us start by describing the best response function for CP 0. Suppose $p_1 \leq V''$. In that case, advertisers would buy ad spaces from CP 1, irrespectively of whether they have already bought ads from CP 0 or not, since the price is surely below the value of a repeated impression. If they put ads on CP 1, however, they will also put them on CP 0 only if p_0 is low enough, i.e. only if $(V' - p_0)q^- + (V' + V'' - p_0 - p_1)q^+ \geq (V' - p_1)q^+$, which results in $p_0 \leq V'q^- + V''q^+$. It follows that the best response for CP 0 is to set $p_0 = V'q^- + V''q^+$ (otherwise, CP 0 would not be able to sell any ad space). Suppose now $p_1 > V''$: in that case, advertisers putting ads on CP 0, would never put them on CP 1, the price being too high. This rules out multi-homing, so all advertisers put ads either on CP 0 or CP 1. Clearly, CP 0 is better off being the player capturing all the market. This happens if and only if $(V' - p_0) \geq (V' - p_1)q^+$ holds. As a consequence, the best response is $p_0 = V'q^- + p_1q^+$.

Let us now describe the best response function for CP 1. Suppose first that $p_0 \leq V'q^- + V''q^+$. Advertisers multi-home if and only if $p_1 \leq V''$. Otherwise, they all converge on one of

the two CPs. However, if $p_1 > V''$, this CP is 0, as condition $(V' - p_0) \geq (V' - p_1) q^+$ holds. It follows that the best response is $p_1 = V''$. Suppose now that $p_0 > V' q^- + V'' q^+$. p_0 is sufficiently high for CP 1 to be able to capture all the market while still setting a higher price than V'' . Indeed, it can easily be verified that condition $(V' - p_0) \leq (V' - p_1) q^+$ holds as long as $p_1 \leq \frac{p_0 - V' q^-}{q^+}$. The threshold on the right hand side of the inequality is strictly higher than V'' as long as $p_0 > V' q^- + V'' q^+$. Hence, by setting $p_1 = \frac{p_0 - V' q^-}{q^+} > V''$, CP 1 is able to capture all the market. Hence, the best response is $p_1 = \frac{p_0 - V' q^-}{q^+}$. We are now in a position to describe the equilibrium. It is quite easy to see that the only mutual best response is such that $p_1 = V''$ and $p_0 = V' q^- + V'' q^+$. This implies that CPs' profits are $\pi_1 = V'' q^+ - F_A$ and $\pi_0 = V' q^- + V'' q^+ - \sum F_i$ and that advertisers multi-home. A similar reasoning applies when the configuration is $(0A,1AB)$, $(0B,1AB)$ and $(,1B)$.

Market configuration $(0i,1i)$, $(0N,1i)$, $(0N,1N)$ with $i \in \{A, B\}$ (and symmetric). Consider now a configuration with all CPs being distributed by only one ISP, i.e. either $(0A,1A)$ or $(0B,1B)$. With a reasoning similar to that of the case of Universal Connection, one can prove that the only equilibrium is such that $p_0 = p_1 = V''$ so that CPs' profits are $\pi_1 = \pi_0 = V'' q^{++} - F_A$. Again, advertisers multi-home.

Market configuration $(0i,1i')$, with $i, i' \in \{A, B\}$ and $i \neq i'$ (and symmetric). Consider a market configuration involving full segmentation, i.e. either $(0A,1B)$ or $(0B,1A)$. If an advertiser puts ads on both CPs, its total surplus would be $(V' - p_0) \frac{1}{2} + (V' - p_1) \frac{1}{2}$. If instead ads are put only on CP j , the surplus is $(V' - p_j) \frac{1}{2}$. In this case, each CP would be a monopolistic outlet for the consumers it reaches. Thus, simply following the previous reasoning, it is easy to show that equilibrium prices are $p_0 = p_1 = V'$ and profits $\pi_1 = \pi_0 = \frac{V'}{2} - F_i$. It is again the case that, in equilibrium, advertisers multi-home.

Consider now a configuration with one CP being distributed by both ISPs, while the other CP being distributed by no ISP. Take, for example, the case $(0AB,1N)$. No advertiser puts an ad on CP 1 since no consumer can reach it. If an advertiser puts ads on CP 0, its total surplus is $V' - p_0$. Thus, the only equilibrium is such that $p_0 = V'$. Hence, CPs' profits are $\pi_1 = 0$, $\pi_0 = V' - \sum F_i$. In this case, advertisers single-home, since they have no benefit from advertising on CP 1. A similar reasoning applies to configuration $(0N,1AB)$.

Market configuration $(0N,1i)$ with $i \in \{A, B\}$ (and symmetric). Finally, consider a configuration with one CP being distributed by one ISP, with the other CP being distributed by none, such as $(0A,1N)$. No advertiser puts an ad on CP1 since no consumer is reached. If an advertiser puts ads on CP 0, its total surplus is $(V' - p_0) q^{++}$. Thus, $p_0 = V'$. Hence,

CPs' profits are $\pi_1 = 0$, $\pi_0 = V'q^+ - F_A$. A similar reasoning applies when the configuration is $(0N,1A)$, $(0N,1B)$ and $(0B,1N)$.

Proof of Proposition 3

Looking at the table provided in Lemma 3, we have

1. Configuration $(0AB,1AB)$ obtains when

$$F_A \leq V''q^- \quad F_B \leq V''q^- \quad V'' \geq F_A + F_B$$

2. $(0AB,1A)$ and $(0A,1AB)$

$$\begin{aligned} F_A &\leq V''q^+ - V' \left(\frac{1}{2} - q^- \right) & V''q^- &< F_B \leq V'q^- - V''(q^{+++} - q^+) \\ F_A + F_B &\leq V''q^+ + V'q^- & F_B &> F_A \end{aligned}$$

and symmetrically for configurations $(0AB,1B)$ and $(0B,1AB)$, exchanging subscript A with subscript B .

3. $(0N,1AB)$ and $(0AB,1N)$

$$\begin{aligned} V''q^+ &< F_A \leq V'q^{--} & V''q^+ &< F_B \leq V'q^{--} \\ V'' &< F_A + F_B \leq V' \end{aligned}$$

4. $(0A,1A)$

$$\begin{aligned} F_A &\leq V''q^{+++} & F_B &> V'q^- - V''(q^{+++} - q^+) \\ F_B - F_A &> \frac{V'}{2} - V''q^{+++} \end{aligned}$$

and symmetrically for configuration $(0B,1B)$, exchanging subscript A with subscript B .

5. (0A,1B) and (0B,1A)

$$\begin{aligned} V'' q^+ - V' \left(\frac{1}{2} - q^- \right) &< F_A \leq \frac{V'}{2} \\ V'' q^+ - V' \left(\frac{1}{2} - q^- \right) &< F_B \leq \frac{V'}{2} \\ -\frac{V'}{2} + V'' q^{+++} &\leq F_A - F_B \leq \frac{V'}{2} - V'' q^{+++} \end{aligned}$$

6. (0N, 1A) and (0A,1N)

$$\begin{aligned} V'' q^{+++} &< F_A \leq V' q^{++} & \frac{V'}{2} &< F_B \\ F_B + F_A &> V' q^- + V'' q^+ & F_B &> F_A \end{aligned}$$

and symmetrically for configuration (0B,1N) and (0N,1B), exchanging subscript A with subscript B .

7. (0N, 1N)

$$F_A > V' q^{++} \quad F_B > V' q^{++} \quad F_B + F_A > V'$$

Setting now $F_i = 0 \ i = A, B$, one easily verifies that only the equilibria described in the claim exist.

Proof of Proposition 4

We proceed as follows: we consider all possible network configurations in turn. Following Proposition 3, we know that each configuration is feasible only for a given set of couples (F_A, F_B) . We identify the candidate equilibrium couples (F_A, F_B) that give rise to the given configuration, using the conditions provided in Proposition 3. Although all the equilibrium couples we identify are such that only one network configuration is induced multiple network configurations could, in principle, arise for a given couple (F_A, F_B) . This requires us to make assumptions regarding the beliefs of ISPs when they evaluate the profitability of unilateral deviations from an equilibrium. We proceed assuming that, if the deviation may induce multiple configurations, the ISP believes that the configuration to arise is always that which entails the smallest profit.

I. Market configuration (0AB,1AB)

From Proposition 3, we know that for this configuration to arise it has to be the case that $F_i \leq V'' q^-$ for $i = \{A, B\}$.³⁰ To describe the equilibria, we divide the feasible region in three mutually exclusive regions of parameters.

a. Case $V'' \leq \frac{V'}{2}$. This case implies that $V'' q^+ - V' (\frac{1}{2} - q^-) \leq V'' q^-$. To begin, we show that any termination fee $F_i \leq V'' q^+ - V' (\frac{1}{2} - q^-)$ for $i = \{A, B\}$ can be ruled out as equilibrium candidates. Indeed, any couple of fees satisfying this condition induces network configuration (0AB,1AB). However, ISP i could increase its fee to $F_i = V'' q^-$, still inducing (0AB,1AB) but making strictly higher profits. Consider now the following set of equilibrium candidates: $F_i \in (V'' q^+ - V' (\frac{1}{2} - q^-); V'' q^-]$, $i = \{A, B\}$. This set of fees induces configuration (0AB,1AB) and brings $\pi_i = 2F_i + \frac{t}{2}$ to each ISP. Assume now ISP A unilaterally deviates by decreasing F_A . It is straightforward that this is never profitable, since the network configuration does not change, but profits made by A are strictly lower. Now, assume that ISP A deviates by increasing F_A . Depending on how large the deviation is, A can induce market configuration (0B,1B) or (0A,1B). From Proposition 3, since $F_B \leq V'' q^{+++}$, (0B,1B) emerges as long as $F_A > \max \left\{ V' q^- - V'' (q^{+++} - q^+); \frac{V'}{2} - V'' q^{+++} + F_B \right\}$. Clearly, this deviation is never profitable, since A gains only $\pi_A = \frac{(3t - \delta(1+\gamma))^2}{18t}$. Configuration (0A,1B) results instead if A sets $V'' q^+ - V' (\frac{1}{2} - q^-) < F_A \leq \frac{V'}{2} - V'' q^{+++} + F_B$.³¹ Within this interval, the most profitable deviation is to set $F_A = \frac{V'}{2} - V'' q^{+++} + F_B$, obtaining $\pi_A = F_B + \frac{V'}{2} - V'' q^{+++} + \frac{t}{2}$. This deviation is profitable compared to the candidate equilibrium we described above if and only if $F_B + \frac{V'}{2} - V'' q^{+++} + \frac{t}{2} > 2F_A + \frac{t}{2}$, where $F_B \in (V'' q^+ - V' (\frac{1}{2} - q^-); V'' q^-]$. Whether the latter condition holds or not depends on the value of V'' compared to V' (see below). Since a symmetric reasoning can be followed for deviations by ISP B , we conclude that all couple of fees such that $F_i \in (V'' q^+ - V' (\frac{1}{2} - q^-); V'' q^-]$ for $i = \{A, B\}$ are an equilibrium and induce network configuration (0AB,1AB) if

$$V'' \geq \left(\frac{V'}{2} + \max \{F_B - 2F_A; F_A - 2F_B\} \right) \frac{1}{q^{+++}} \equiv S_1(F_A, F_B)$$

where $F_i \in (V'' q^+ - V' (\frac{1}{2} - q^-); V'' q^-]$ for $i = \{A, B\}$. Simple algebra shows that threshold $S_1(F_A, F_B)$ is minimized when $F_A = F_B = V'' q^-$. Hence, among the set of candidate equilibrium fees $F_i \in (V'' q^+ - V' (\frac{1}{2} - q^-); V'' q^-]$ for $i = \{A, B\}$, the couple $F_A = F_B = V'' q^-$ is that for which feasibility conditions are least restrictive. Substituting and rearranging, we

³⁰These constraints imply that $F_A + F_B \leq V''$ is always satisfied.

³¹Observe that, since we are considering $F_i \in (V'' q^+ - V' (\frac{1}{2} - q^-); V'' q^-]$, we have that $\min \left\{ \frac{V'}{2}; \frac{V'}{2} - V'' q^{+++} + F_B \right\} = \frac{V'}{2} - V'' q^{+++} + F_B$.

obtain therefore that

$$V'' \geq V' \left(\frac{3t}{6t + \delta} \right) = S_1 \left(V'' q^-, V'' q^- \right) \equiv S_{UC}^U$$

is a sufficient condition for the equilibrium inducing $(0AB, 1AB)$ to take place.

b. Case $\frac{V'}{2} < V'' < \frac{V'(3t-\delta\gamma)}{3t+\delta(1-\gamma)}$. This implies that $V'' q^- < \min \{ V'' q^+ - V' (\frac{1}{2} - q^-); V' q^- - V'' (q^{+++} - q^+) \}$. Suppose both ISPs set $F_i \leq V'' q^-$ inducing the network configuration $(0AB, 1AB)$ and obtaining $\pi_i = 2F_i + \frac{t}{2}$. Assume ISP A unilaterally deviates by increasing F_A . This can induce market configuration $(0B, 1AB)$ or $(0B, 1)$.³² If $F_A > V' q^- - V'' (q^{+++} - q^+)$, A induces market configuration $(0B, 1B)$, which is clearly not a profitable deviation. If A sets $F_A = V' q^- - V'' (q^{+++} - q^+)$, it gives rise to market configuration $(0B, 1AB)$ and obtains $\pi_A = V' q^- - V'' (q^{+++} - q^+) + \frac{(3t-\delta\gamma)^2}{18t}$. This deviation is profitable if $V' q^- - V'' (q^{+++} - q^+) + \frac{(3t-\delta\gamma)^2}{18t} > 2F_A + \frac{t}{2}$, where $F_A = V' q^- - V'' (q^{+++} - q^+)$. However, this inequality is never verified. Of course, a similar reasoning can be followed for ISP B . We can conclude that network configuration $(0AB, 1AB)$ with termination fees $F_i \leq V'' q^-$ for $i = \{A, B\}$ is always an equilibrium.

c. Case $\frac{V'(3t-\delta\gamma)}{3t+\delta(1-\gamma)} \leq V'' \leq V'$. This implies that $V' q^- - V'' (q^{+++} - q^+) \leq V'' q^- < V'' q^+ - V' (\frac{1}{2} - q^-)$. Assume both ISPs $i = \{A, B\}$ set $F_i \in (V' q^- - V'' (q^{+++} - q^+); V'' q^-]$ thereby inducing network configuration $(0AB, 1AB)$ and profits $\pi_i = 2F_i + \frac{t}{2}$. Assume ISP A unilaterally deviates. If ISP A increases F_A it gives rise to market configuration $(0B, 1B)$. That is not a profitable deviation. If ISP A decreases its fee, it still induces the same market configuration and earn more profits. Since similar reasoning can be followed for ISP B , market configuration $(0AB, 1AB)$ with $F_i \in (V' q^- - V'' (q^{+++} - q^+); V'' q^-]$ for $i = \{A, B\}$ is always an equilibrium.

II. Market configuration $(0i, 1i')$, with $i, i' \in \{A, B\}$ and $i \neq i'$

For concreteness, we focus on configuration $(0A, 1AB)$. All other configurations can be discussed in a similar way. From Proposition 3, we know that this market configuration is feasible if the following conditions jointly hold $F_A \leq V'' q^+ - V' (\frac{1}{2} - q^-)$, $V'' q^- < F_B \leq V' q^- - V'' (q^{+++} - q^+)$ and $F_B > F_A$.³³ We now argue that the only fees that can sustain this network configuration at equilibrium are $F_A = V'' q^+ - V' (\frac{1}{2} - q^-)$ and $F_B = V' q^- - V'' (q^{+++} - q^+)$. They are therefore our candidate equilibrium. Indeed, lower termination fees (still within the above intervals) are dominated, since an ISP can always increase its fee, induce the same configuration and gain strictly higher profits. ISPs' profits

³²Since $\frac{V'}{2} < V'' q^{+++}$ by assumption, network configuration $(0B, 1A)$ can never arise at equilibrium.

³³Note that condition $F_A + F_B \leq V'' q^+ + V' q^-$ is always verified if these inequalities hold.

are $\pi_A = 2(V''q^+ - V'(\frac{1}{2} - q^-)) + \frac{(3t+\delta\gamma)^2}{18t}$ and $\pi_B = V'q^- - V''(q^{+++} - q^+) + \frac{(3t-\delta\gamma)^2}{18t}$. We now verify that no profitable unilateral deviation from our candidate equilibrium exists. As for configuration $(0AB,1AB)$ we consider three mutually exclusive regions of parameters.

a. Case $V'' \leq \frac{V'}{2}$. This implies $V''q^+ - V'(\frac{1}{2} - q^-) \leq V''q^-$. Assume that ISP A unilaterally deviates by decreasing F_A . This cannot be a profitable deviation for A , since it induces the same network configuration, but A gains less profits. Now, assume ISP A deviates by increasing F_A . By so doing, ISP A can either induce market configuration $(0B,1B)$ or $(0A,1B)$. If $F_A > \frac{V'}{2} - V''q^{+++} + F_B = \frac{V'}{2} + V'q^- + V''q^+ - 2V''q^{+++}$, configuration $(0B,1B)$ arises. This is not a profitable deviation for A . Instead, if ISP A sets $F_A = \min\left\{\frac{V'}{2}; \frac{V'}{2} - V''q^{+++} + F_B\right\}$, it gives rise to market configuration $(0A,1B)$ and obtains profits $\pi_A = \min\left\{\frac{V'}{2}; \frac{V'}{2} + V'q^- + V''q^+ - 2V''q^{+++}\right\} + \frac{t}{2}$. We now need to distinguish among two subcases. Suppose that $V'q^- - V''(q^{+++} - q^+) \geq V''q^{+++}$. This implies that $\min\left\{\frac{V'}{2}; \frac{V'}{2} + V'q^- + V''q^+ - 2V''q^{+++}\right\} = \frac{V'}{2}$. Thus, the deviation is profitable if $\frac{V'}{2} + \frac{t}{2} > 2(V''q^+ - V'(\frac{1}{2} - q^-)) + \frac{(3t+\delta\gamma)^2}{18t}$, that is if and only if

$$V'' < \left(V' \left(1 + \frac{\delta\gamma}{6t}\right) + \frac{t}{2} - \frac{(3t + \delta\gamma)^2}{18t}\right) \left(\frac{6t}{9t + 2\delta + 3\delta\gamma}\right) \equiv S_2$$

If instead $V'q^- - V''(q^{+++} - q^+) < V''q^{+++}$, we have that $\min\left\{\frac{V'}{2}; \frac{V'}{2} + V'q^- + V''q^+ - 2V''q^{+++}\right\} = \frac{V'}{2} + V'q^- + V''q^+ - 2V''q^{+++}$. The deviation is profitable if and only if

$$V'' < \left(V' \left(\frac{1}{2} + \frac{2\delta\gamma}{6t}\right) + \frac{t}{2} - \frac{(3t + \delta\gamma)^2}{18t}\right) \left(\frac{3t}{3t + \delta\gamma}\right) \equiv S_3$$

Consider now possible unilateral deviations by ISP B . Suppose it decreases F_B . By setting $F_B = V''q^-$, B induces market configuration $(0AB,1AB)$ and obtains profits equal to $\pi_B = 2V''q^- + \frac{t}{2}$. This is profitable if and only if $2V''q^- + \frac{t}{2} > V'q^- - V''(q^{+++} - q^+) + \frac{(3t-\delta\gamma)^2}{18t}$ holds, that is if and only if

$$V'' > \left(V' \left(\frac{1}{2} - \frac{\delta\gamma}{6t}\right) - \frac{t}{2} + \frac{(3t - \delta\gamma)^2}{18t}\right) \left(\frac{6t}{6t + \delta - 2\delta\gamma}\right) \equiv S_4$$

Suppose now B deviates increasing F_B : this can only induce market configuration $(0A,1A)$, which is never profitable. We conclude that the couple of fees $F_A = V''q^+ - V'(\frac{1}{2} - q^-)$ and $F_B = V'q^- - V''(q^{+++} - q^+)$ are an equilibrium only if $V'' \geq S_2$ and $V'' \leq S_4$ for $V'q^- - V''(q^{+++} - q^+) \geq V''q^{+++}$ and if $V'' \geq S_3$ and $V'' \leq S_4$ for $V'q^- - V''(q^{+++} - q^+) < V''q^{+++}$. Nevertheless, it can be shown that these conditions are never jointly verified. Therefore, network configurations $(0i,1i')$, with $i, i' \in \{A, B\}$ and $i \neq i'$ never arise at

equilibrium.

b. Case $\frac{V'}{2} < V'' < \frac{V'(3t-\delta\gamma)}{3t+\delta(1-\gamma)}$. This implies $V''q^- < \min\{V''q^+ - V'(\frac{1}{2} - q^-); V'q^- - V''(q^{+++} - q^+)\}$. Assume ISP B unilaterally deviates by decreasing F_B to $V''q^+ - V'(\frac{1}{2} - q^-) - \varepsilon$, where $\varepsilon > 0$ and arbitrarily small. This induces market configuration $(0B,1AB)$ or $(0AB,1B)$ so B earns $\pi_B = 2(V''q^+ - V'(\frac{1}{2} - q^-) - \varepsilon) + \frac{(3t+\delta\gamma)^2}{18t}$. Since $2(V''q^+ - V'(\frac{1}{2} - q^-) - \varepsilon) + \frac{(3t+\delta\gamma)^2}{18t} > V'q^- - V''(q^{+++} - q^+) + \frac{(3t-\delta\gamma)^2}{18t}$ is verified, this deviation is always profitable. It follows that configurations $(0A,1AB)$, $(0AB,1A)$ and their symmetric are never equilibria.

c. Case $\frac{V'(3t-\delta\gamma)}{3t+\delta(1-\gamma)} \leq V'' \leq V'$. This implies $V'q^- - V''(q^{+++} - q^+) \leq V''q^- < V''q^+ - V'(\frac{1}{2} - q^-)$. Since $V'q^- - V''(q^{+++} - q^+) < V''q^+ - V'(\frac{1}{2} - q^-)$ constraint $F_B > F_A$ is always violated. Hence, configurations $(0A,1AB)$, $(0AB,1A)$ and their symmetric are never equilibria.

III. Market configuration $(0i,1i')$, with $i, i' \in \{A, B\}$ and $i \neq i'$ (and symmetric)

Following Proposition 3, we know that this market configuration is feasible if conditions $V''q^+ - V'(\frac{1}{2} - q^-) < F_i \leq \frac{V'}{2}$ $i = A, B$ and $-\frac{V'}{2} + V''q^{+++} \leq F_i - F_{i'} \leq \frac{V'}{2} - V''q^{+++}$ $i, i' \in \{A, B\}, i \neq i'$ hold. Among all couples of fees that satisfy the above conditions, the equilibrium candidate is $F_A = F_B = \frac{V'}{2}$. Indeed, starting from any other couple, an ISP could always marginally increase its fee, induce the same configuration and gain higher profits. Consequently, $\pi_A = \pi_B = \frac{V'}{2} + \frac{t}{2}$ are profits made in our equilibrium candidate. Once again, we verify whether this is actually the equilibrium working dividing the parameter space in three separate regions.

a. Case $V'' \leq \frac{V'}{2}$. This implies that $V''q^+ - V'(\frac{1}{2} - q^-) \leq V''q^-$. Suppose ISP A deviates by decreasing F_A to $\min\{F_{i'} - \frac{V'}{2} + V''q^{+++} - \varepsilon; V''q^{+++}\} = V''q^{+++} - \varepsilon$, where $\varepsilon > 0$ and small. This is the largest value of F_A inducing configuration $(0A,1A)$ (given that $F_B = \frac{V'}{2}$). By so doing, A earns profits $\pi_A = 2(V''q^{+++} - \varepsilon) + \frac{(3t+\delta(1+\gamma))^2}{18t}$. The deviation is profitable if $2(V''q^{+++} - \varepsilon) + \frac{(3t+\delta(1+\gamma))^2}{18t} > \frac{V'}{2} + \frac{t}{2}$, that is if and only if (for ε that goes to zero)

$$V'' > \left(\frac{V'}{2} - \frac{(3t + \delta(1 + \gamma))^2}{18t} + \frac{t}{2} \right) \left(\frac{3t}{3t + \delta(1 + \gamma)} \right) \equiv S_{TF}^U$$

Suppose now A deviates by increasing F_A . By so doing, A loses the only CP that it has on board (and the fee it would pay). Hence, this deviation is not profitable. Summing up, the market configuration $(0i,1i')$ with $F_A = F_B = \frac{V'}{2}$ is an equilibrium only if $V'' \leq S_{TF}^U$.

b. Case $\frac{V'}{2} < V'' < \frac{V'(3t-\delta\gamma)}{3t+\delta(1-\gamma)}$. This implies $V''q^- < \min\{V''q^+ - V'(\frac{1}{2} - q^-); V'q^- - V''(q^{+++} - q^+)\}$. Suppose ISP A deviates decreasing its fee. By setting $F_A =$

$\min \left\{ F_B - \frac{V'}{2} + V'' q^{+++} - \varepsilon; V'' q^{+++} \right\} = V'' q^{+++} - \varepsilon$ it can induce market configuration $(0A,1A)$ and earn $\pi_A = 2(V'' q^{+++} - \varepsilon) + \frac{(3t+\delta(1+\gamma))^2}{18t}$. As in the above case, the deviation is profitable only if $V'' > S_5$. In the region of parameters we are considering, however, the latter condition is never verified. Hence, configuration $(0i,1i')$ never arises at equilibrium.

c. Case $\frac{V'(3t-\delta\gamma)}{3t+\delta(1-\gamma)} \leq V'' \leq V'$. This implies $V' q^- - V''(q^{+++} - q^+) \leq V'' q^- < V'' q^+ - V'(\frac{1}{2} - q^-)$. Since $V'' q^{+++} > \frac{V'}{2}$, constraint $-\frac{V'}{2} + V'' q^{+++} \leq F_i - F_{i'} \leq \frac{V'}{2} - V'' q^{+++}$ is always violated. This configuration is never feasible.

IV. Market configuration $(0N,1ii')$, with $i, i' \in \{A, B\}$ and $i \neq i'$ (and symmetric)

Following Proposition 3, this market configuration is feasible if $V'' q^+ < F_A \leq V' q^{--}$.³⁴ The region where this configuration is feasible is a subset of the region where $(0i,1i')$ is feasible. For a given termination fee, ISP i earns the same profits under configuration $(0N,1ii')$ or $(0ii',1N)$ and $(0i,1i')$ (since the profits on the consumers' side in both cases are $\frac{t}{2}$). Hence, an ISP can always deviate from this equilibrium by raising its fee, so as to induce $(0i,1i')$.

V. Market configuration $(0i,1i)$, $(0N,1i)$, $(0N,1N)$ with $i \in \{A, B\}$ (and symmetric)

An ISP always finds profitable to deviate from this configuration. Indeed, it is straightforward that by reducing its fee, the ISP carrying no CP can strictly increase its revenues by inducing at least one CP to sign up.

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