Preventing competition using side payments: when non-neutrality creates barriers to entry

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Abstract Network neutrality is often advocated by content providers, stressing that side payments to Internet Service Providers would hinder innovation. However, we also observe some content provider actually paying those fees. This paper intends to explain such behaviors through economic modeling, illustrating how side payments can be a way for an incumbent content provider to prevent new competitors from entering the market. We investigate the conditions under which the incumbent can benefit from such a barrier-to-entry, and the consequences of that strategic behavior on the other actors: content providers, users, and the Internet Service Provider. We also describe how the Nash bargaining solution concept can be used to determine the side payment.

Keywords Network neutrality · Barrier to entry · Game theory

1 Introduction

The *network neutrality debate* is shaking up not only the telecommunication world but also governments, with laws passed worldwide. This vivid debate comes from Internet Service Providers (ISPs) complaining about some distant but heavy resource-consuming Content Providers (CPs) creating stress on their networks while not paying anything to them, because connected to the Internet through another ISP. The complainants therefore threat to block or slow down the traffic of those CPs if they

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do not pay a side fee in order to participate to the network infrastructure maintenance and upgrade. This created a lot of protests from user associations and content providers claiming that it could harm innovation, freedom of speech, and the universality of access principle among other issues. The issue is therefore basically whether the network should forbid such payments and other types of differentiation. For more information about the history of the network neutrality debate, and arguments from both sides, the reader is advised to go to [3, 7, 9, 17] among the numerous publications on the topic.

Surprisingly, some big CPs, while officially strongly in favor of neutrality, are now giving side payments to ISPs. This is typically what Google (a major CP because of YouTube traffic) is doing, for instance in France with the main ISP Orange[1], Netflix with Comcast and Verizon[2], etc.

A question is then: what reason could drive big CPs to accept such side payments, when governments and user associations seem to fight on their side? In this paper, we investigate the relevance of a potential reason: accepting side payments when able to pay them could create a *barrier to entry* for potential competitors. Indeed, new entrants may incur initial costs and not have the same economies of scale as incumbents; therefore they may not be able to afford such payments. And from the incumbent perspective, the potential loss due to competitors entering the market may overcome the cost of side payments.

Note that some other interpretations for side payments have been proposed in the literature. Generally, side payments can be exchanged between actors to improve the coordination among them. They can be used in supply chains to improve their efficiency when several producers are involved [8]; or, closer to our problem, to avoid conflicts, an actor being paid for not participating in a later conflicting interaction [6, 15].

In the context of the net neutrality debate, and with the same interpretation of side payments as ours (from CPs to ISPs), a possible justification for such payments is that they can benefit both ISPs (receiving those payments) and CPs (although delivering them). This holds in situations where ISPs compete [2] and even when ISPs are monopolistic and need side payments to invest more in infrastructure [10]. To the best of our knowledge, the present paper, along with its preliminary conference version [16], is the first contribution developing the idea of side payments' use as a barrier to entry for CPs willing to enter the market and compete with incumbents.

The definition of barrier to entry has been a topic of discussion in the economic literature. It has first been defined by Bain in 1956 as “anything that allows incumbent firms to earn above-normal profits without the threat of entry" [1]. Other definitions followed; a historical development of definitions and a classification was provided in [12] with four different concepts of barrier to entry: i) an economic barrier to entry as a cost incurred by a new entrant but not by an incumbent, ii) an antitrust barrier to entry as a cost delaying entry and as a consequence reducing social welfare compared to an immediate cost, iii) a primary barrier to entry as a cost that constitutes a barrier to entry on its own, and iv) an ancillary barrier to entry as a cost that (indirectly)

1 http://www.theverge.com/2013/1/19/3894182/french-isp-orange-says-google-pays-to-send-traffic

2 http://arstechnica.com/information-technology/2014/05/21/see-which-isps-google-microsoft-and-netflix-trade-internet-traffic-with/

reinforces other barriers to entry. A side payment falls into the third category (primary barrier to entry) since directly incurred by CPs and potentially preventing market entrance if benefits are not sufficient.

We propose in this paper to introduce and analyze a model describing a simple Internet supply chain with two content providers, end users, and ISPs as intermediaries. Demand from users will be assumed to depend on the access price at the ISP, and to follow a (traditional) linear form. We will analyze several scenarios:

- without side payment (a neutral network) and with competition between ISPs,
- with side payments and competition,
- and with side payments and only the incumbent CP.

We will compare the outputs obtained in these scenarios. We will particularly look at revenues of CPs and the ISP, and consumer surplus. The goal is to get some insight about what strategy each actors should choose and whether or not some regulation rules should be imposed. If collusion between the incumbent CP and the ISP is beneficial, we will determine the side payment as a Nash bargaining solution [11], an axiomatic concept describing a solution of negotiation between players. Refinements of the model, considering uncertainties about the potential new entrant and the temporal aspects of its entry, are also investigated in this paper.

Note that modeling and analysis of barrier to entry in markets has of course been already studied, in a spirit somewhat similar to our work. A. Dixit in his seminal work [4] considers also a direct competition between an incumbent and an entrant providers, with linear demand too, but using a model less representative of the Internet, without ISPs as intermediaries while ISPs make important decisions here. [5] is another paper making use of a basic model, but working on a different issue: determining the optimal number of firms in a market depending on fixed costs.

The rest of this paper is organized as follows. In Section 2, the mathematical model is presented, as well as the order of decisions among players, those playing first strategically anticipating the subsequent decisions of the others. Section 3 then provides the resulting values of revenues and consumer surplus in the three scenarios: no side payment, side payment but only the incumbent CP, and side payments with the two CPs. Those outputs are compared and conditions under which creating barriers to entry are beneficial for the incumbent provider are provided. Section 4 then describes how the incumbent CP and the ISP can negotiate the price, defined as the Nash bargaining solution. Two possible extensions of that model are then investigated. In Section 5 we relax the assumption that the ISP-incumbent CP pair knows perfectly how the newcomer will perform (in terms of market shares, bandwidth usage, and revenues): the reasoning is then based on expectations. Section 6 considers the temporal aspect, modeling the evolution of market shares after the possible entrance of the competitor, and focusing on how long it would take that newcomer to cover its entry cost when side-payments are imposed or not. Finally, Section 7 concludes our paper and discusses extensions of the model.

2 Model

We consider the model presented in Figure 1. It describes a supply chain made of two content providers (CPs) in competition, end users, and one ISP as an intermediary. We just consider two CPs, believing that it is to provide some insight (which is the goal of the paper), but this can be generalized and will be the purpose of future work. To simplify the analysis, users are treated as a continuum, meaning that no user has individually an impact on the system (i.e., they are assumed infinitesimal). The total mass of base users is defined as $D_{\max}$.

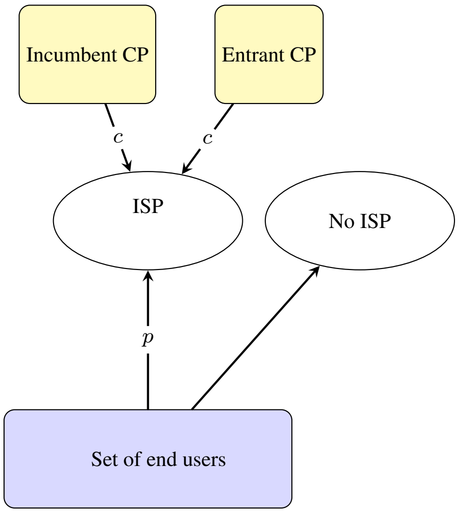

Figure 1 Representation of relations between users, ISP and CPs

Figure 1 also shows the economic relations between actors: there is *potentially* a cost c (side payment) per unit of volume that CPs transfer to the ISP, and a subscription fee p per unit of customer paid by customers to the ISP. We also assume a revenue r_i (respectively r_e) per unit of request for the incumbent CP (respectively the entrant CP). Those revenues may for instance be due to advertisements displayed on the CP site and seen or clicked by customers, but could apply to other types of revenue (sales, subscriptions, etc.).

2.1 User demand

The subscriber demand (mass of users subscribing to the ISP) D is assumed to be linear in price, of the form

$$D = (D_{\max} - \alpha p)^+$$

where α is the price sensitivity parameter and $(\cdot)^+ = \max(\cdot, 0)$. This type of model is traditional in economics [11] and has often been used in models studying barriers to entry such as [4].

We define from total demand D the mass D_i of requests at the incumbent and the mass D_e of users making use of the new entrant service. Without loss of generality the request unit of mass is chosen such that in the case where the incumbent is alone, we have $D_i = D$. In that situation, we also have $D_e = 0$. On the other hand when both propose their services, $D_i = \gamma_i D$ and $D_e = \gamma_e D$ with $\gamma_i, \gamma_e > 0$ being the proportion of requests at each CP. Typically, we will consider that the arrival of the new entrant results in a loss of traffic for the incumbent (hence $\gamma_i < 1$), due to less subscribers or connections, but also that $\gamma_i + \gamma_e \geq 1$, meaning that users might use both services (there is no exclusivity) when both CPs are present. In other words, the total traffic increases upon the new entrant arrival, due to a more attractive catalog, while traffic for the incumbent decreases because in part moved to the new entrant.

Note here that demand does not depend on content, more exactly on whether the two CPs are present or not. This can be justified by the fact that the CPs we are considering are just a part of the Internet content, and having one or two substitutable CPs does not limit the user range of activities (or has a negligible impact).

A metric of interest as a measure of consumer satisfaction from the users' side is Consumer Surplus (S), which is defined as the aggregated difference between the maximum prices consumers are willing to pay and the prices actually paid. Graphically, it is the hashed area in Figure 2.

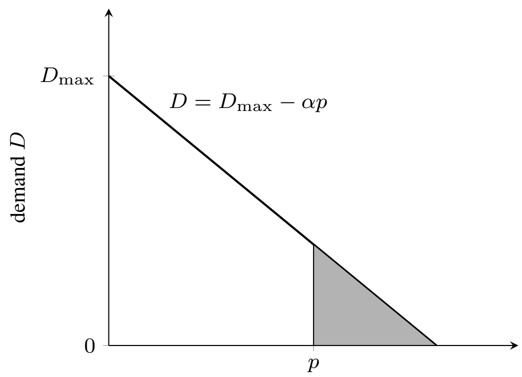

Figure 2 Consumer surplus with a linear demand.

2.2 Internet Service Provider

The ISP is characterized by its revenue

$$R = pD + cv_i + cv_e$$

where

– pD corresponds to the revenue due to subscriptions from users;

– the other terms correspond to the side payments: v_i and v_e are the total volume of requests for each CP, with

$$v_i = \beta_i D_i \quad \text{and} \quad v_e = \beta_e D_e$$

with β_i and β_e the (average, per time unit) units of volume consumed per request to each CP;

2.3 Content Provider Revenues

Recall that we have defined D_i and D_e as the masses of requests of the incumbent and new entrant CPs respectively, and r_i and r_e the respective revenues generated per (mass unit of) request.

The revenues of the incumbent and entrant CPs are then respectively:

$$R_i = r_i D_i - c v_i = (r_i - \beta_i c) D_i$$
$$R_e = (r_e - \beta_e c) D_e.$$

2.4 Order of decisions

CPs, ISP and users have to make strategical decisions, but they are not all made at the same time scale. The decisions are as follows:

1. First, the ISP and incumbent CP decide (through a negotiation) the side payment;
2. Then the ISP decides the subscription price p;
3. Finally users adapt their demand to the proposed services and price.

Decisions are made strategically: actors playing first make their decision anticipating the subsequent decisions of the others. Hence those decisions can be analysed using the backward induction method [14].

This model is studied in the next section in the case of three scenarios:

1. no side payments and both CPs in the market;
2. side payments and only the incumbent provider;
3. side payments and both CPs.

The interest of considering those three scenarios, and comparing them, is manyfold: First, it will help the incumbent provider to decide whether or not to be in favor of side payments and their level of magnitude, by comparing the revenues to the cases where the new entrant is there. Second, it helps the ISP to decide a strategy on side payments by looking at its revenue, and also if negotiating with the incumbent is beneficial as opposed to the threat of network neutrality regulation. Finally, the same comparison is helpful for regulatory bodies to investigate if it harms competition and consumer surplus.

Note that in all cases, the subscription price is chosen to maximize the ISP revenue

$$R = pD + (c\beta_i\gamma_i + c\beta_e\gamma_e)D,$$

where we set $\gamma_e = 0$ and $\gamma_i = 1$ if the incumbent is alone. To simplify the notations, define

$$C := c(\beta_i\gamma_i + \beta_e\gamma_e)$$

as the average side payment per (unit of) user. From $R = (p + C)(D_{\max} - \alpha p)$, we get

$$p = \frac{D_{\max}}{2\alpha} - \frac{C}{2}$$

as the price maximizing the ISP revenue.

Note that this price could be negative if $C > D_{\max}/\alpha$ but this would mean a demand larger than the base $D_{\max}$. Taking $p = 0$ is then optimal.

3 Outputs for given side payments

This section describes the outputs for the three scenarios and then deduces the strategic decisions of players.

3.1 Without side payments

When no side payments are applied, i.e., $c = 0$, we can use our previous derivations (optimal price, corresponding demand value) to get new expressions for revenues and consumer surplus. This yields

$$\begin{aligned}
p &= \frac{D_{\max}}{2\alpha}\\
D &= \frac{D_{\max}}{2}\\
R_i &= r_i\gamma_i\frac{D_{\max}}{2}\\
R_e &= r_e\gamma_e\frac{D_{\max}}{2}\\
R &= \frac{{D_{\max}}^2}{4\alpha}\\
\mathrm{S} &= \int_{\frac{D_{\max}}{2\alpha}}^{\frac{D_{\max}}{\alpha}} (D_{\max} - \alpha p)\mathrm{d}p = \frac{{D_{\max}}^2}{8\alpha}.
\end{aligned}$$

3.2 With side payments but only the incumbent content provider

When the incumbent provider is in a monopolistic position, and is charged side payments by the ISP, then our model still applies, with $\gamma_i = 1$, $\gamma_e = 0$, and $C = c\beta_i$. For a given side payment c, we get, following the same substitution procedure as in the previous subsection,

$$
\begin{aligned}
p &= \frac{D_{\max}}{2\alpha} - \frac{c\beta_i}{2} \text{ (assumed non-negative)}\\
D = D_i &= \frac{D_{\max}}{2} + \alpha\frac{c\beta_i}{2}\\
R_i &= (r_i - \beta_i c)\left(\frac{D_{\max}}{2} + \alpha\frac{c\beta_i}{2}\right)\\
R &= \frac{1}{4\alpha}\left(D_{\max} + \alpha c\beta_i\right)^2\\
\mathrm{S} &= \int_{\frac{D_{\max}}{2\alpha}-\frac{c\beta_i}{2}}^{\frac{D_{\max}}{\alpha}} (D_{\max} - \alpha p)\mathrm{d}p\\
&= \frac{{D_{\max}}^2 + 2D_{\max}c\beta_i\alpha + c^2\beta_i^2\alpha^2}{8\alpha}.
\end{aligned}
$$

3.3 With side payments and the two content providers

The case of two CPs and side payments yields

$$
\begin{aligned}
p &= \frac{D_{\max}}{2\alpha} - \frac{c(\beta_i\gamma_i + \beta_e\gamma_e)}{2}\\
D &= \frac{D_{\max}}{2} + \alpha\frac{c(\beta_i\gamma_i + \beta_e\gamma_e)}{2}\\
R_i &= \gamma_i(r_i - c\beta_i)\left(\frac{D_{\max}}{2} + \alpha\frac{c(\beta_i\gamma_i + \beta_e\gamma_e)}{2}\right)\\
R_e &= \gamma_e(r_e - c\beta_e)\left(\frac{D_{\max}}{2} + \alpha\frac{c(\beta_i\gamma_i + \beta_e\gamma_e)}{2}\right)\\
R &= \frac{1}{4\alpha}\left(D_{\max} + \alpha c(\beta_i\gamma_i + \beta_e\gamma_e)\right)^2\\
\mathrm{S} &= \frac{{D_{\max}}^2 + 2D_{\max}c(\beta_i\gamma_i + \beta_e\gamma_e)\alpha + c(\beta_i\gamma_i + \beta_e\gamma_e)^2\alpha^2}{8\alpha}.
\end{aligned}
$$

3.4 Comparison and resulting strategic decisions

We can make several remarks when comparing the outputs for the three scenarios:

1. First, the new entrant will not enter the market if its revenue is negative, i.e., if $c > r_e/\beta_e$. The incumbent CP, if wishing to prevent the new entrant to reach customers, must agree on side payments of at least that amount. Clearly also, the incumbent cannot accept a non-negative revenue, hence we must have $c \leq r_i/\beta_i$. It implicitly means that the revenue per unit of data r_i/β_i has to be larger for the incumbent than that r_e/β_e of the new entrant. This will be assumed from now and is a reasonable assumption.

2. But in order for the incumbent to be in favor of side payments, and therefore to create a barrier to entry, its revenue (when alone) has also to be larger than when there is no side payments. It happens when $(r_i - \beta_i c)(D_{\max} + \alpha c\beta_i) > r_i\gamma_i D_{\max}$, i.e., if c is in the interval

$$\left(\frac{-(D_{\max}-\alpha r_i) - \sqrt{\beta_i^2(D_{\max}-\alpha r_i)^2 + 4\alpha\beta_i^2 r_i(1-\gamma_i)D_{\max}}}{2\alpha\beta_i^2},\right.$$

$$\left.\frac{-(D_{\max}-\alpha r_i) + \sqrt{\beta_i^2(D_{\max}-\alpha r_i)^2 + 4\alpha\beta_i^2 r_i(1-\gamma_i)D_{\max}}}{2\alpha\beta_i^2}\right).$$

   The left bound of the interval being negative, we actually just need c to be smaller than the right bound.
   Note that the incumbent can at the same time pay a level of fee to ensure that the new entrant will not be there and ask for no side payments publicly. This is typically what would happen if the revenue with side payment and barrier to entry is i) larger than that with the new entrant (and still a side payment), but ii) smaller than that with a “neutral" ISP. It corresponds to the situation when the CP would prefer the neutral situation, but being unsure that it will be applied, goes to the best of two evils. It may also be a strategical behavior even if monopoly plus side payments is the best option, in terms of image and in order to better negotiate the level of payments (see next section). It may explain what Google is doing in France: paying a side payment to the major ISP (Orange), but asking for a neutral network.
3. The ISP has also to agree that the level of side payment increases its revenue R. This is always the case with respect to a neutral situation. But, in general, a single CP will be preferred if $c_s\beta_i > c_2(\beta_i\gamma_i + \beta_e\gamma_e)$ where c_s is the side payment when there is only one CP (through a corresponding negotiation), and c_2 when there are two. To look at a *sufficient* condition with simplified notations, when $c_s = c_2$, we just need $\beta_i > \beta_i\gamma_i + \beta_e\gamma_e$. But this inequality is true if the incumbent induces a large amount of traffic (typically what Google does with YouTube).
4. Consider now consumer surplus. If a regulator investigates the consequences of side payments, they are actually beneficial from a customer point of view. This comes from the fact that due to side payments, the ISP can reduce the access price, hence higher levels of demand and satisfaction from end users. This situation is actually at the expense of CPs.

Example 1 Figure 3 displays the revenues in terms of c when $D_{\max} = 10$, $\alpha = 1$, $\beta_i = 0.7$, $\beta_e = 2$, $r_i = 6$, $r_e = 3$, $\gamma_i = 0.7$, and $\gamma_e = 0.5$ (arbitrary values). We display the revenues R_i and R in the competitive case when $c < r_e/\beta_e$, and in the monopolistic case when $r_e/\beta_e \leq c < r_i/\beta_i$. We clearly see the threshold at $r_e/\beta_e = 1.5$ where the new CP strategy changes from entering the market to not entering it. We also see that the incumbent CP is better off with a side payment when above but close to that threshold.

Table 1 presents some numerical computations for the three scenarios, for two values of c. If the price is $c = 0.5$, the incumbent CP even gets a higher revenue than in the two other cases when alone, but with such a c, the new entrant would be

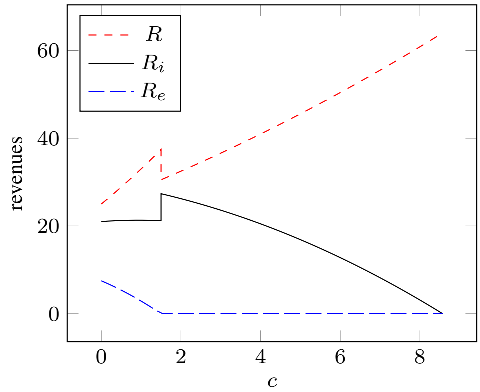

Figure 3 Revenues of the ISP (R), the incumbent CP (R_i), and the new entrant CP (R_e), in terms of the side payment c.

Table 1 Some numerical values for the three scenarios for two values of c

c	Scenario	p	D	R_i	R_e	R	S
—	No side payment	5	5	21	7.5	25	12.5
0.5	Monopoly	4.825	5.175	29.23875	—	26.780625	13.3903125
0.5	Side payment and competition	4.6275	5.3725	21.2482375	5.3725	28.86375625	14.43187812
2	Monopoly	4.3	5.7	26.22	—	32.49	16.245
2	Side payment and competition	3.51	6.49	20.8978	-3.245	42.1201	21.06005

present; we would be in the situation of side payment and competition. On the other hand, we see that with a price $c = 2$ the new entrant should not enter the market, and the incumbent gets a higher revenue than without side payment or with a side payment smaller than $r_e/\beta_e = 1.5$ (something clear on Figure 3). The revenue of the ISP is also higher than without side payments, hence $c = 2$ benefits both the ISP and incumbent CP with respect to a neutral situation, hence an incentive to cooperate. In terms of consumer surplus, the higher the side payment, the better it is.

4 Side payments negotiation

In the previous section, we were discussing the optimal strategies when the side payment was fixed. The purpose of this section is to investigate how those payments can be defined, if they are eventually authorized by regulators. Actually several possibilities exist. A first one would be that the price be chosen by the ISP trying to maximize its revenue. It is clear from the revenue expressions that it would be set at a level such that the CP revenue is becoming 0, at the same time increasing demand because most ISP revenue is then paid by the CP. In such a case, there would be a strong opposition and lobbying from CPs, and the risk of neutrality regulation would be very large.

We consider here the situation where there is a negotiation between the incumbent CP and the ISP about the side payment. The solution of this negotiation is assumed to be the result of an axiomatic model called *Nash bargaining solution* [14]. Placed into our context, the ISP and incumbent CP independently choose a set of acceptable side payments, the ones providing a non-negative revenue in the interval $(r_e/\beta_e, r_i/\beta_i)$ ensuring for the incumbent to impose barriers to entry. If there is no agreement, a threat is executed: due to possible complaints related to the network neutrality debate, the threat is no side payment, $c = 0$. Since this negotiation may end up with several equilibria, the most likely to be played is the one maximizing the product of the utilities minus the utility at the threat [13]. In other words, that equilibrium side payment c maximizes

$$K := (R_i(c) - R_i(0))(R(c) - R(0)),$$

where $R_i(c)$ and $R(c)$ are the revenues with side payment c, and that maximizer is called the Nash bargaining solution.

Since $c > r_e/\beta_e$, only the incumbent CP is present and

$$K = \left((r_i - \beta_i c)\left(\frac{D_{\max}}{2} + \alpha\frac{c\beta_i}{2}\right) - r_i\gamma_i\frac{D_{\max}}{2}\right)\frac{c\beta_i}{4}\left(c\alpha\beta_i + 2D_{\max}\right).$$

We can differentiate this term with respect to c and get optimum values (that will be summarized to solving polynoms in c of degree three). Instead of providing this analytic list which does not bring much insight, we illustrate on our running example the Nash bargaining solution for c.

Example 2 Figure 4 displays K in terms of c (still when $D_{\max} = 10$, $\alpha = 1$, $\beta_i = 0.7$, $\beta_e = 2$, $r_i = 6$, $r_e = 3$, $\gamma_i = 0.7$, and $\gamma_e = 0.5$). One can check that, with

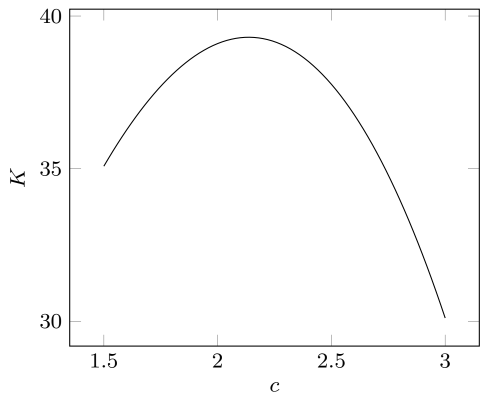

Figure 4 K in terms of c.

our parameters, K is maximized at $c = 2.137012$. Table 2 presents the output at this value. The incumbent CP revenue is not maximized (because smaller than when $c = 2$), but much larger than when there is no side payment. The same applies for the ISP. It is indeed a compromise on which they both agree.

We also display in Figure 5 the evolution of that Nash bargaining c in terms of the proportion of requests β_i that the incumbent still attracts when the new entrant is

Table 2 Numerical values for c as the Nash bargaining solution.

c	Scenario	p	D	R_i	R_e	R	S
2.137012	Nash Bargaining	4.2520458	5.7479542	25.88931223	—	33.03897748	16.51948874

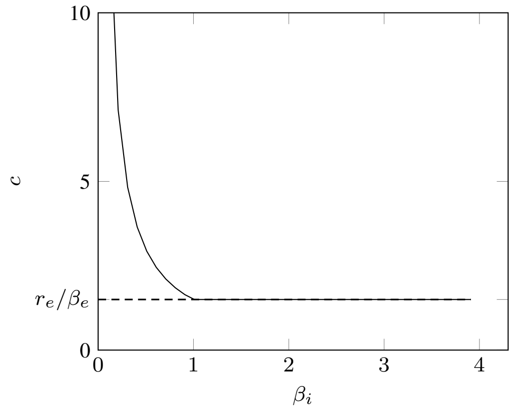

Figure 5 Nash bargaining c in terms of β_i.

present, all other parameters being defined as before. This side payment c is larger than the threshold $r_e/\beta_e = 1.5$ for “small" values of β_i, and sticks to that threshold as soon as $\beta_i \geq 1.0$.

5 Anticipating a potential competitor

Our previous analysis was assuming that the parameters related to a new entrant were known. It would work if side payments were decided when the competitor enters the market (and assuming all parameters could again be derived quickly). Though, the side payments are not likely to be that reactive to the market: (i) it would be too visible that they are barriers to entry, and (ii) negotiations would take time.

We assume here that the new entrant parameters are unknown, but that there is a common knowledge about the distribution of the parameters of a potential new entrant. The goals of the incumbent and the ISP are then to maximize their respective *expected* revenues.

More specifically, we consider that the parameters r_i and β_i are fixed and known, but that there is a joint density function $f(\cdot)$ on parameters $r_e, \beta_e, \gamma_e, \gamma_i$. Depending on the random values, for a fixed c

- if $r_e - c\beta_e \geq 0$, the competitor enters the market and we get the values $R_i(c)$ and $R(c)$ computed in Subsection 3.3;
- if $r_e - c\beta_e < 0$, the competitor does not enter the market and we get the values $R_i(c)$ and $R(c)$ computed in Subsection 3.2.

From this, we can easily (numerically) compute the expected revenues for the incumbent $\mathbb{E}[R_i(c)] = \int R_i(c) f(r_e, \beta_e, \gamma_e, \gamma_i) \mathrm{d}r_e \mathrm{d}\beta_e \mathrm{d}\gamma_e \mathrm{d}\gamma_i$, new entrant $\mathbb{E}[R_e(c)]$, and ISP $\mathbb{E}[R(c)]$.

The price c can be negotiated between the ISP and the incumbent CP trying to maximize their expected revenue. Again as in the previous section, the Nash bargaining solution c maximizes

$$K = (\mathbb{E}[R_i(c)] - \mathbb{E}[R_i(0)])(\mathbb{E}[R(c)] - \mathbb{E}[R(0)]).$$

Deriving theoretical formulas seems intractable, but we are able to obtain numerical results about expected revenues in terms of c and then about the negotiation between the ISP and the incumbent CP.

Example 3 Assume as in our previous example that $D_{\max} = 10$, $\alpha = 1$, $\beta_i = 0.7$ and $r_i = 6$. We also assume that β_e, r_e and γ_e are uniformly distributed over respectively $[\beta_i/2, 2\beta_i]$, $[0, 1.2r_i]$ and $[0.7, 1]$, and that $\gamma_i = 1.1 - \gamma_e$. Figure 6 displays the expected revenues in terms of c. The revenue of the new entrant decreases with c,

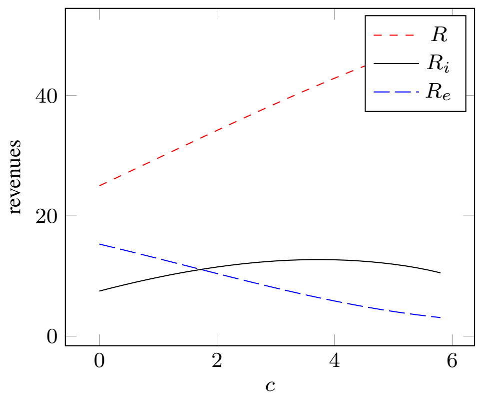

Figure 6 Expected revenues in terms of c.

while that of the ISP increases. For the incumbent CP on the other hand, there is a maximum. Due to the randomization, there is no discontinuity, in contrast to Figure 3.

Figure 7 displays the value of K in terms of c. when using the expected revenues. It is maximized close to $c = 4.6$. Even if the revenue of the ISP keeps increasing with c, there is an interest to trade off with the incumbent CP, hence a Nash bargaining solution that is finite, and larger than the price maximizing the incumbent CP revenue.

6 Adding temporality to the model

In the previous sections, we have considered that the new entrant would attract a proportion γ_e of the demand (and incurs a loss of a proportion $1 - \gamma_i$ in the incumbent's requests), and studied the values of the side payment for which the new entrant is deterred from playing in the market.

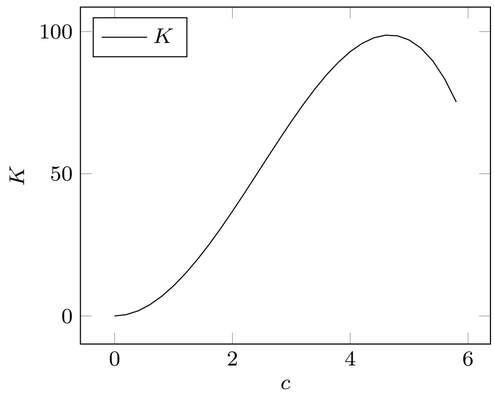

Figure 7 K in terms of c in the expected case.

But we did not enter the details of what happens over time when the newcomer CP enters the market. Indeed, it is not reasonable to assume that a proportion γ_e of the total demand (i.e., requests) goes to the new entrant immediately after it entered, while a proportion $1-\gamma_i$ immediately stops using the services of the incumbent CP. Instead, we can reasonably expect that users progressively adopt the new entrant (while some also progressively leave the incumbent), and γ_e and γ_i then correspond to the *stationary* proportions of users for each CP, i.e., after convergence of the adoption process. The reasoning in the previous sections was therefore for that stationary situation. In particular, the barrier to entry intended to ensure that the new entrant would not make benefits in that situation. However, if we consider the dynamic setting, lower values of the side payments may be enough to prevent the newcomer from entering the market: that newcomer could indeed make benefit in the long run, but would have to face losses over a significant amount of time. Depending on how long the newcomer can "survive" without making benefits, and the maximum amount of debt it can accumulate, this may be sufficient to discourage it from entering the game.

We study this time aspect in the present section. More specifically, considering that the newcomer enters the market at time 0, the proportion $\gamma_i(t)$ (resp., $\gamma_e(t)$) of requests choosing the incumbent (resp., the newcomer) CP is assumed of the form

$$\gamma_i(t) = \gamma_i + (1-\gamma_i)e^{-\omega t}$$
$$\gamma_e(t) = \gamma_e - \gamma_e e^{-\omega t},$$

where the parameter ω represents the speed at which the changes in user behavior occur. The digital market being very volatile, reasonable values for ω are of the order of $1/2$ per year, meaning that a CP can lose as much as 40% of its demand within one year if it performs badly (here, if $\gamma_i = 0$).

As expected, at $t = 0$ the new entrant has no customers ($\gamma_e(0) = 0$) and all requests go to the incumbent ($\gamma_i(0) = 1$), and the long-term proportions of the previous sections are the limits when t is large.

Note that if no newcomer CP enters the market, we are already at the stationary situation and nothing changes over time, hence we are at the situation analyzed in Subsection 3.2.

To carry out the temporal analysis, we consider a discount factor δ, so that one monetary unit in t years is worth $e^{-\delta t}$ monetary units of today. And over a time period spanning from 0 to T, an actor with revenue per time unit $U(t)$ at time t is sensitive to the average discounted revenue

$$\bar{U}(T) := \frac{\delta}{1 - e^{-\delta T}} \int_{t=0}^{T} U(t) e^{-\delta t} \mathrm{d}t.$$

Similarly, we will denote by $\bar{R}(T)$, $\bar{R}_i(T)$, and $\bar{R}_e(T)$ the average discounted revenue of the ISP, the incumbent CP, and the newcomer CP, respectively, with the time horizon T.

In all generality, we should allow the price p and the side-payment level c to vary over time. But we think it is more realistic to consider them fixed since users are likely to be reluctant to frequent price changes, and side-payments are decided through negotiations and contracts, and are difficult to change. At most one change in those values is considered here, at time 0 when those strategic decisions are made. As a result, the total user demand $D = [D_{\max} - \alpha p]^+$ will be constant over time.

6.1 No newcomer entrance

Assume that the newcomer does not enter the market; then $\gamma_i(t) = 1$ for all t, and recalling the results from Subsection 3.2 we have constant values for all revenues. Hence for any T we have

$$\begin{aligned}
\bar{R}_i(T) &= (r_i - \beta_i c)\left(\frac{D_{\max}}{2} + \alpha \frac{c\beta_i}{2}\right) \\
\bar{R}(T) &= \frac{1}{4\alpha}\left(D_{\max} + \alpha c \beta_i\right)^2,
\end{aligned}$$

and the other values of interest are

$$\begin{aligned}
p &= \frac{D_{\max}}{2\alpha} - \frac{c\beta_i}{2} \text{ (assumed non-negative)} \\
D = D_i &= \frac{D_{\max}}{2} + \alpha \frac{c\beta_i}{2} \\
\mathrm{S} &= \frac{{D_{\max}}^2 + 2D_{\max} c\beta_i \alpha + c^2 \beta_i^2 \alpha^2}{8\alpha}.
\end{aligned}$$

6.2 Arrival of the newcomer

Assuming that the side-payment level c is chosen before the ISP price p, and following the classical backward induction method, we analyze how p should be set when c is fixed.

6.2.1 ISP revenue-maximizing price

For given values of c and p, the ISP revenue at time t is

$$R(t) = Dp + Dc(\beta_i\gamma_i(t) + \beta_e\gamma_e(t)).$$

Therefore, the average revenue at the horizon T is

$$\begin{aligned}\bar{R}(T) &= Dp + Dc(\beta_i\gamma_i + \beta_e\gamma_e) + \\ &\quad + Dc\frac{\beta_i(1-\gamma_i) - \beta_e\gamma_e}{1-e^{-\delta T}}\delta\int_{t=0}^{T} e^{-(\omega+\delta)t}\mathrm{d}t \\ &= Dp + DC + D\tilde{C}\frac{\delta}{\omega+\delta}\frac{1-e^{-(\omega+\delta)T}}{1-e^{-\delta T}}\end{aligned}$$

where $C := c(\beta_i\gamma_i + \beta_e\gamma_e)$ as previously, and $\tilde{C} := c(\beta_i(1-\gamma_i) - \beta_e\gamma_e) = c\beta_i - C$.

When T is fixed, we can define the constant

$$C' := C + \tilde{C}\frac{\delta}{\omega+\delta}\frac{1-e^{-(\omega+\delta)T}}{1-e^{-\delta T}},$$

so that the revenue of the ISP is

$$\bar{R}(T) = D \times (p + C'),$$

and as in Section 3 the revenue-optimizing price is

$$p = \frac{D_{\max}}{2\alpha} - \frac{C'}{2}, \qquad \text{assumed positive,}$$

leading to

$$\bar{R}(T) = \frac{1}{4\alpha}\left(D_{\max} + \alpha C'\right)^2.$$

Note that $C' > C$, so (for a given side-payment level) the price set here is below the one we obtained when ignoring the transient phase and focusing only on the limit case (what we did in Section 3). In the numerical examples shown later on, we will consider that the ISP has a very large horizon T, so that $C' = C + \tilde{C}\frac{\delta}{\omega+\delta}$.

Now, let us express the revenues of both CPs as functions of the side-payment c.

6.2.2 Revenue for the incumbent CP

At time t, the incumbent CP gets revenue per time unit $(r_i - \beta_i c)\gamma_i(t)D$, so over a time horizon T_i, its average discounted revenue is

$$\bar{R}_i(T_i) = (r_i - \beta_i c)D\left(\gamma_i + (1-\gamma_i)\frac{\delta}{\omega+\delta}\frac{1-e^{-(\omega+\delta)T_i}}{1-e^{-\delta T_i}}\right),$$

with $D = D_{\max} - \alpha p = \frac{D_{\max}+C'}{2}$.

6.2.3 Revenue for the newcomer CP

Similarly, at time t the newcomer CP gets (if it enters the market) a revenue per time unit $R_e(t) = (r_e - \beta_e c)\gamma_e(t)D$. But entering the market also involves a fixed cost (investments in the new service and/or in infrastructure or licensing) which we denote by E_e. That fixed cost had no impact when focusing on the long-term revenue only as in Section 3, but here with a finite horizon T_e or a nonzero discount rate δ, the question for the new entrant becomes: will the aggregated discounted revenues in the first T_e time units (say, years) be enough to cover the entry investment E_e?

Our model allows to answer that question: the aggregated discounted revenues for the newcomer between times 0 and T_e can indeed be expressed as

$$\int_{t=0}^{T_e} e^{-\delta t} R_e(t)\mathrm{d}t = (r_e - \beta_e c)D\gamma_e \left(\frac{1 - e^{-\delta T_e}}{\delta} - \frac{1 - e^{-(\omega+\delta)T_e}}{\omega + \delta} \right). \quad (1)$$

As a result, if the newcomer can sustain being nonprofitable for a duration at most T_e, then it will enter the market if and only if

$$(r_e - \beta_e c)D\gamma_e \left(\frac{1 - e^{-\delta T_e}}{\delta} - \frac{1 - e^{-(\omega+\delta)T_e}}{\omega + \delta} \right) > E_e. \quad (2)$$

$D_{\max}$	α	β_i	β_e	r_i	r_e	γ_i	γ_e	δ	ω	E_e	T_i	T_e
10	1	0.7	2	6	3	0.7	0.5	0.04	0.5	20	10	10

Table 3 The parameters used for the numerical analysis

With respect to Section 3, having the side payment be such that $r_e - \beta_e c < 0$ is sufficient, but not necessary anymore to prevent the newcomer from entering. Figure 8 shows the aggregated revenue of (1) when the time horizon T_e varies and the other parameters are given in Table 3: while Section 3 suggests a minimum side payment of $r_e/\beta_e = 1.5$, the figure shows that lower values can be sufficient to deter the newcomer from entering the market, especially if it has a short time horizon: in a neutral network ($c = 0$) the newcomer would make benefits in less than five years, while it would take more than ten years with $c = 1$.

This effect, and the dependence on the fixed entry cost E_e, is further illustrated on Figure 9 showing how long it takes for the newcomer to cover that fixed cost with the revenues obtained from entering the market and attracting users. When there is no fixed cost ($E_e = 0$), we find again that the newcomer does not enter the market if $c > r_e/\beta_e = 1.5$, and makes immediate benefits otherwise. But with a fixed cost to enter the market, even side payments below r_e/β_e significantly harden the work for the newcomer, delaying by several years the time to rentability.

6.3 When can the ISP-incumbent CP pair create a barrier to entry?

As before, a barrier-to-entry side payment can be agreed upon between the ISP and the incumbent CP when the three conditions below are met.

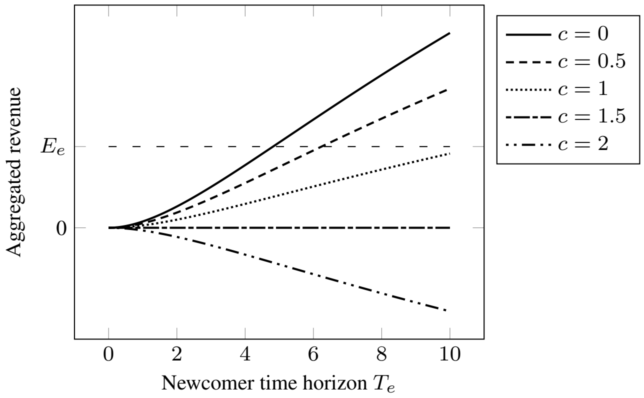

Figure 8 Cumulated discounted revenue over an horizon T_e for the newcomer CP and comparison with its fixed cost E_e. The ISP computes its price based on an infinite time horizon ($T = \infty$).

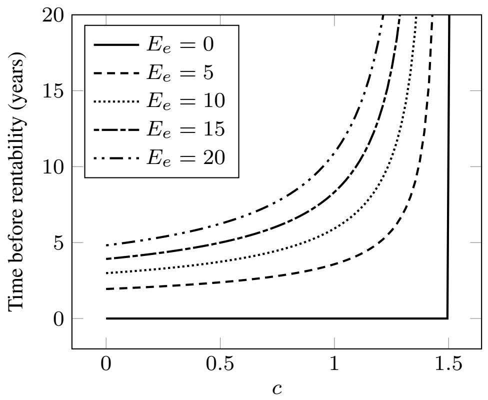

Figure 9 Time for the newcomer CP to cover its fixed cost E_e depending on the side payment c. The ISP computes its price based on an infinite time horizon ($T = \infty$).

1. The newcomer is effectively deterred from entering the market, i.e., (2) is satisfied.
2. The CP prefers paying the side payment (and being alone) than having to face the competitor in a neutral network. In the former case, as seen in Subsection 6.1 the average discounted revenue $\bar{R}_i(T_i)$ is $(r_i - \beta_i c)\left(\frac{D_{\max}}{2} + \alpha\frac{c\beta_i}{2}\right)$, while in the latter case (taking $c = 0$ in (1)) it equals

$$\frac{D_{\max} r_i}{2}\left(\gamma_i + (1-\gamma_i)\frac{\delta}{\omega+\delta}\frac{1-e^{-(\omega+\delta)T_i}}{1-e^{-\delta T_i}}\right).$$

Defining $\bar{\gamma}_i := \gamma_i + (1-\gamma_i)\frac{\delta}{\omega+\delta}\frac{1-e^{-(\omega+\delta)T_i}}{1-e^{-\delta T_i}}$, this amounts as in Section 3 to

$$c \leq \frac{-(D_{\max} - \alpha r_i) + \sqrt{\beta_i^2 (D_{\max} - \alpha r_i)^2 + 4\alpha\beta_i^2 r_i (1-\bar{\gamma}_i) D_{\max}}}{2\alpha\beta_i^2}.$$

3. And the ISP also prefers this situation to the neutral (and competitive) one, i.e.,

$$\frac{1}{4\alpha}\left(D_{\max} + \alpha c \beta_i\right)^2 \geq \frac{1}{4\alpha} {D_{\max}}^2,$$

which is always the case.

Summarizing, one has the conditions on the parameters for having the possibility of a barrier-to-entry side payment that benefits both the ISP and the incumbent CP. As an example, we display on Figure 10 the values of the parameters γ_i, γ_e such that those conditions are met (the domain below the curve for a given T_e), when the other parameter values are those given in Table 3. The figure illustrates that, at least for our parameters, a barrier to entry is very likely to occur: only when the incumbent performs very well (i.e., maintains a large market share γ_i when the newcomer enters the market), such a barrier to entry may be undoable, because the incumbent is not too harmed by competition. Also, when the new entrant has a short time horizon (needs to rapidly cover its entry costs) then, as expected, it is more vulnerable to barriers to entry.

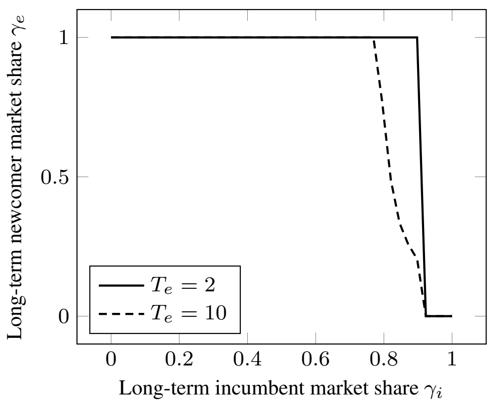

Figure 10 Below the curves, a barrier-to-entry is feasible and benefits both the incumbent CP and the ISP.

7 Conclusions

In this paper, we have introduced a simple model representing the Internet supply chain, and analyzed the relevance for incumbent CPs to agree to pay side payments (depending on parameter values) to ISPs in order to introduce a barrier to entry for competitors. This helps to understand the current behavior of some big CPs, paying those fees despite militating against non-neutral networks. We believe that even if simple, the presented model provides some insight on the consequences on all categories of actors.

Our main contribution is the development of a model and analysis tools to understand such phenomena. Our illustrations are based on arbitrarily-chosen numerical values. An important next step is to carry out econometric studies to fit those parameters to some specific cases. Such an approach was not possible here because of the secrecy around commercial agreements among actors in the Internet. But with access to those data, one can directly apply our method to be able to anticipate the impact of side payments on newcomer entries and the (possible) optimal side payment level. For example, the model can be used by an incumbent content provider wishing to avoid the arrival of a new competitor, or by a regulator (with access to CP-ISP commercial agreements) to determine whether competition is hindered and an intervention is necessary.

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