



HAL
open science

Side Payments as Barriers to Entry in Non-Neutral Networks

Bruno Tuffin

► **To cite this version:**

| Bruno Tuffin. Side Payments as Barriers to Entry in Non-Neutral Networks. 2015. hal-01149214v1

HAL Id: hal-01149214

<https://inria.hal.science/hal-01149214v1>

Preprint submitted on 6 May 2015 (v1), last revised 8 Sep 2015 (v2)

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Side Payments as Barriers to Entry in Non-Neutral Networks

Bruno Tuffin

Inria, France

Email: bruno.tuffin@inria.fr

Abstract—In the network neutrality debate, content providers fight against side payments imposed by ISPs, arguing that it could slow down innovation. But at the same time some big providers actually pay those fees while still officially in favor of neutrality. To better understand this strategic behavior, this paper proposes a simple model providing some insight on whether or not paying side payments for an incumbent provider is a way to create barriers to entry for competitors. It also investigates the economic consequences on all actors: incumbent and new entrant content providers, users, and the ISP. We then describe how the side payment can be determined as a Nash bargaining solution.

I. INTRODUCTION

The *network neutrality debate* is shaking up not only the telecommunication world but also countries 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 network while not paying anything to them because connected to the Internet through another ISP. They therefore threat to block or slow down their traffic if they do not pay a side fee in order to participate to the network infrastructure maintenance sand 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. For more about the history of the network neutrality debate, and arguments from both sides, the reader is advised to go to [1]–[4] 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 Orange¹, Netflix with Comcast and Verizon², etc.

A question is then: what reason drives 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 than incumbents; therefore they may not be able to afford such payments. On the other hand, the cost of side payments for incumbent providers may be overcome by the potential loss due to competitors entering the market.

Barrier to entry definition 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” [5]. Other definitions followed. A historical development of definitions and a classification was provided in [6] 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) 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 with no side payments (a neutral network) and competition between ISPs, side payments and the same competition, or 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 [7], an axiomatic concept describing a solution of negotiation between players.

Note that modeling and analysis of barrier to entry in markets has of course been already studied, in a spirit

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/>

somewhat similar to our work. A. Dixit in his seminal work [8] 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, whereas ISPs make here important decisions. [9] is another work 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 II, the mathematical model is presented, as well as the order of decision among players, those playing first strategically anticipating the subsequent decisions of the others. Section III 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 IV then describes how the incumbent CP and the ISP can negotiate the price, defined as the Nash bargaining solution. Finally Section V concludes our paper and discusses extensions of the model.

II. 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 .

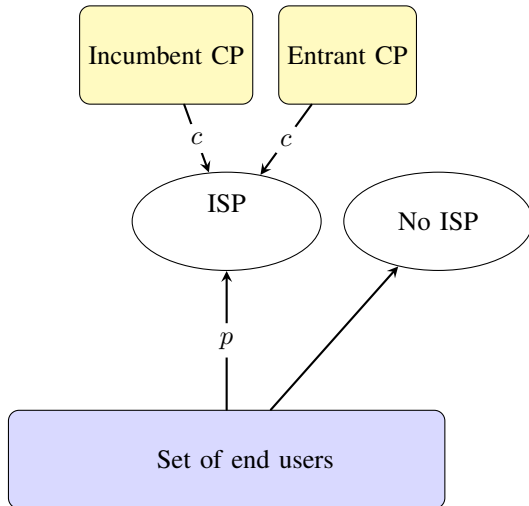


Figure 1. Representation of relations between users, ISP and CPs

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 customer 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.).

A. Users

Demand (mass of users) d is assumed to be linear in price,

$$d = (D - \alpha p)^+$$

where α is the price sensitivity parameter and $(\cdot)^+ = \max(\cdot, 0)$. This type of model is traditional in economics [7] and has often been used in models studying barriers to entry such as [8].

We also decompose the total demand d into d_i , the mass of users making use of the service of the incumbent and d_e the mass of users making use of the new entrant service. In the case where the incumbent is alone, we have $d_i = d$ and $d_e = 0$. On the other hand when both propose their services, $d_i = \gamma_i d$ and $d_e = \gamma_e d$ with $\gamma_i, \gamma_e \in (0, 1]$. We will assume $\gamma_i + \gamma_e \geq 1$, meaning that users might use both services (there is no exclusivity) when they are both present.

Note here that demand does not depend on content, more exactly on whether or not 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 users 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 (CS). Recall the definition of (aggregated) CS: it is the aggregated difference between the maximum price a consumer is willing to pay and the actual paid price. Mathematically, it is the hashed area in Figure 2.

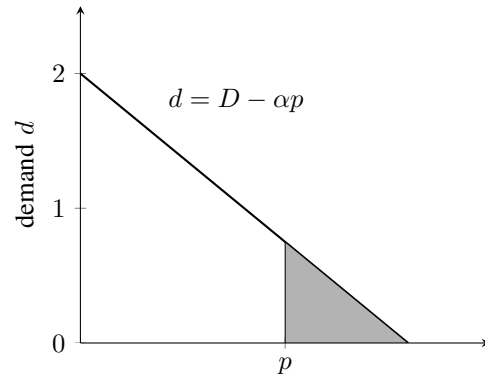


Figure 2. Consumer surplus with a linear demand.

B. ISP

The ISP is characterized by its revenue

$$R = pd + cv_i + cv_e$$

where

- v_i and v_e are the corresponding units of volume 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) units of volume consumed per user;

- pd corresponds to the revenue due to subscriptions from users.

C. CPs

Recall that we have defined d_i and d_e as the masses of users of the incumbent and new entrant CPs respectively, and r_i and r_e the respective revenues generated per (mass unit of) customer.

The revenues of CPs are then:

$$\begin{aligned} R_i &= r_i d_i - cv_i = (r_i - \beta_i c) d_i \\ R_e &= (r_e - \beta_e c) d_e. \end{aligned}$$

D. Order of decisions

CPs, ISP and users have to take strategic decisions, but they are not all taken 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 taken strategically, by backward induction: even when playing first, actors will make their decision anticipating what will be the subsequent decisions of the others.

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 many folds: first, it will help the incumbent provider to decide whether or not to be in favor of side payments, and at which level, by comparing the revenues to the case where the new entrant is there, with or without side payments. For the ISP, it also helps 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 $R = (p + C)(D - \alpha p)$, we get

$$p = \frac{D}{2\alpha} - C$$

as the price maximizing the ISP revenue.

Remark that this price could be negative if $C > D/(2\alpha)$ but this would mean a demand larger than the base D (in the expression of demand, we should have set D as a max). Taking $p = 0$ is then optimal.

III. OUTPUTS FOR GIVEN SIDE PAYMENTS

A. Without side payments

It amounts to assume $c = 0$.

Replacing this value of c in the price optimization and substituting the optimal price and corresponding demand value in the expressions of revenues and CS, we get

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

B. With side payments but only the incumbent CP

Then $\gamma_i = 1$, $\gamma_e = 0$, and $C = c\beta_i$. For a given side payment c , we get, following the same substitution procedure than in previous subsection,

$$\begin{aligned} p &= \frac{D}{2\alpha} - c\beta_i \quad (\text{assumed non-negative}) \\ d = d_i &= \frac{D}{2} + \alpha c\beta_i \\ R_i &= (r_i - \beta_i c)(D/2 + \alpha c\beta_i) \\ R &= \frac{D}{2\alpha} \left(\frac{D}{2} + \alpha c\beta_i \right) \\ CS &= \int_{\frac{D}{2\alpha} - c\beta_i}^{\frac{D}{2\alpha}} (D - \alpha p) dp \\ &= \frac{D^2 + 4Dc\beta_i\alpha + 4c^2\beta_i^2\alpha^2}{8\alpha}. \end{aligned}$$

C. With side payments and the two CPs

It gives in this case

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

D. 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 barrier to entry, its revenue has also to be larger than when the new entrant is there (with side payments), but also when there is no side payments.
 - First, the situation when it is beneficial to pay c for the incumbent to and be alone in the market rather than paying and being in competition with the same c is summarized by the equation (comparing the respective expressions of R_i):

$$D/2 + \alpha c\beta_i > \gamma_i \left(\frac{D}{2} + \alpha c(\beta_i\gamma_i + \beta_e\gamma_e) \right).$$

Note that for γ_i small enough, this will always be true (that is, the new entrant make the incumbent lose too many clients; it is better to pay enough side payments to avoid its presence). But what amount c of payment is required to be in favor of side payments? The above equation is equivalent to

$$(1 - \gamma_i) \frac{D}{2\alpha} > c(\gamma_i(\beta_i\gamma_i + \beta_e\gamma_e) - 1).$$

- If $\gamma_i(\beta_i\gamma_i + \beta_e\gamma_e) - 1 \leq 0$, this will always be true;

- If $\gamma_i(\beta_i\gamma_i + \beta_e\gamma_e) - 1 > 0$, we need $c < ((1 - \gamma_i) \frac{D}{2\alpha}) / (\gamma_i(\beta_i\gamma_i + \beta_e\gamma_e) - 1)$.

- In addition, being in monopoly with side payments has to be preferred to the (neutral) competitive case without fee. The former situation is preferred to the latter if $(r_i - \beta_i c)(D/2 + \alpha c\beta_i) > r_i\gamma_i \frac{D}{2}$, i.e., if c is in the interval

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

The left bound of the interval being negative, we actually just need c to be smaller than the right bound.

Compiling those two results, the incumbent CP will clearly prefer paying the ISP for its traffic and create barriers to entry if

$$c < \min \left(((1 - \gamma_i) \frac{D}{2\alpha}) / (\gamma_i(\beta_i\gamma_i + \beta_e\gamma_e) - 1), \frac{-(D/2 - \alpha r_i) + \sqrt{\beta_i^2(D/2 - \alpha r_i)^2 + 2\alpha\beta_i^2 r_i(1 - \gamma_i)D}}{2\alpha\beta_i^2} \right)$$

if $\gamma_i(\beta_i\gamma_i + \beta_e\gamma_e) - 1 > 0$, and just if

$$c < \frac{-(D/2 - \alpha r_i) + \sqrt{\beta_i^2(D/2 - \alpha r_i)^2 + 2\alpha\beta_i^2 r_i(1 - \gamma_i)D}}{2\alpha\beta_i^2}$$

if $\gamma_i(\beta_i\gamma_i + \beta_e\gamma_e) - 1 \leq 0$.

Remark 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 larger than that with the new entrant (and still a side payment), but smaller than that with a "neutral" ISP. It corresponds to the situation when the CP would prefer the neutral behavior, but being unsure that it will be applied, goes to the best of two evils. It may also be strategical even if monopoly and side payments is the best option, in terms of image and in order to better negotiate the level of payments (see next section). 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 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. If $c_s = c_2$, 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).

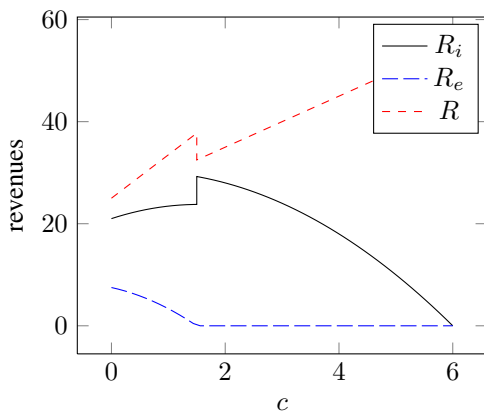


Figure 3. Revenues in terms of c .

- 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 instead and only.

Example 1. Figure 3 displays the revenues in terms of c when $D = 10$, $\alpha = 1$, $\beta_i = 1$, $\beta_e = 2$, $r_i = 6$, $r_e = 3$, $\gamma_i = 0.7$, and $\gamma_e = 0.5$. 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 I 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 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 when no side payment, hence is better solution for both the ISP and incumbent CP, and therefore an incentive to cooperate. In terms of consumer surplus, the higher the side payment, the better it is.

IV. 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 chosen by the ISP trying to maximize its revenue. But doing that, it is clear from the revenue expressions that it would be set at a level such that the CP revenue is becoming 0, but increasing demand because most ISP revenue is then paid by the CP. But that way, 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* [10]. 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 $(r_e/\beta_e, r_i/\beta_i)$ to ensure for the incumbent to impose barriers to entry. If there is no agreement, a threat is executed: due to eventual complains related to the network neutrality debate, the threat is no side payment, $c = 0$. Since this negotiation may end up with several equilibria, as in [11] the most likely to be played is the one maximizing the product of the utilities minus the utility at the threat. 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

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

We can differentiate with respect to c this term and get optimum values (that will be summarized to solving polynomials in c of degree two but listing the numerous cases depending on whether or not the solutions are below or above the bounds of interval $(r_e/\beta_e, r_i/\beta_i)$). 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 $D = 10$, $\alpha = 1$, $\beta_i = 1$, $\beta_e = 2$, $r_i = 6$, $r_e = 3$, $\gamma_i = 0.7$, and $\gamma_e = 0.5$). One can check that, with our parameters, K is maximized just at $c = 2.09715$. Table II 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 Nash bargaining c in terms of β_i when the other parameters are defined as above. We clearly see here that this side payment c is larger than the threshold $r_e/\beta_e = 1.5$ for “small” values of β_i , sticks to that threshold as soon as $\beta_i \geq 1.4$.

c	Scenario	p	d	R_i	R_e	R	CS
—	No side payment	5	5	21	7.5	25	12.5
0.5	Monopoly	4.5	5.5	30.25	—	27.5	15.125
0.5	Side payment and competition	4.15	5.85	22.5225	5.85	29.25	17.11125
2	Monopoly	3	7	28	—	35	24.5
2	Side payment and competition	1.6	8.4	23.52	-4.2	42	35.28

Table I
SOME NUMERICAL VALUES FOR THE THREE SCENARIOS FOR TWO VALUES OF c

c	Scenario	p	d	R_i	R_e	R	CS
2.09715	Nash Bargaining	2.90285	7.09715	27.69911188	—	35.48575	25.18476906

Table II
NUMERICAL VALUES FOR c AS THE NASH BARGAINING SOLUTION.

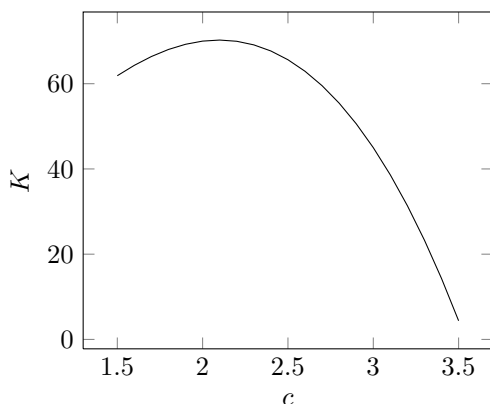


Figure 4. K in terms of c .

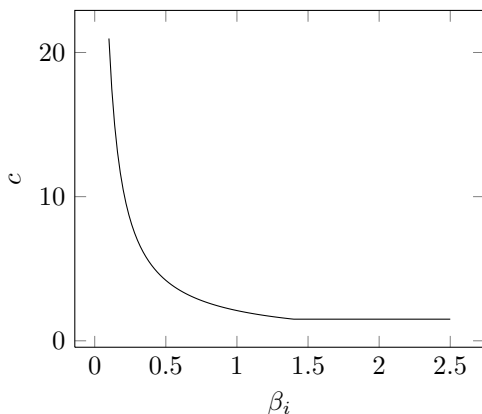


Figure 5. Nash bargaining c in terms of β_i .

V. 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 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 consequence on all categories of actors.

In terms of future work, one assumption we would like to relax is the known parameter values for the new entrant. Indeed, it is not easy to determine before negotiating the side payment what would be the new entrant provider's revenue, market share, etc. We would like to replace those deterministic values by known distributions (or beliefs based on experience) and then try to maximize expected revenues.

REFERENCES

- [1] P. Crocioni, "Net neutrality in Europe: Desperately seeking a market failure," *Telecommunications Policy*, vol. 35, no. 1, pp. 1 – 11, 2011. [Online]. Available: <http://www.sciencedirect.com/science/article/pii/S0308596110001461>
- [2] P. Maillé, P. Reichl, and B. Tuffin, "Internet governance and economics of network neutrality," in *Telecom. Eco. - Selected Results of the COST Action IS605 EconTel*, A. Hadjiantonis and B. Stiller, Eds. Springer Verlag, 2012, pp. 108–116.
- [3] T. Lenard and R. May (Eds.), *Net Neutrality or Net Neutering: Should Broadband Internet Services be Regulated*. Springer, 2006.
- [4] T. Wu, "Network neutrality, broadband discrimination," *Journal of Telecom. and High Tech.*, 2003.
- [5] J. Bain, *Barriers to New Competition*. Cambridge, MA: Harvard University Press, 1956.
- [6] R. P. McAfee, H. M. Mialon, and M. A. Williams, "Economics and antitrust barriers to entry," 2003, <http://vita.mcafee.cc/PDF/Barriers2Entry.pdf>.
- [7] P. Maillé and B. Tuffin, *Telecommunication Network Economics: From Theory to Applications*. Cambridge University Press, 2014.
- [8] A. Dixit, "A model of duopoly suggesting a theory of entry barriers," *Bell Journal of Economics*, vol. 10, no. 1, pp. 20–32, 1979.
- [9] D. Heger and K. Kraft, "Barriers to entry and profitability," ZEW - Zentrum für Europäische Wirtschaftsforschung / Center for European Economic Research, ZEW Discussion Papers 08-071, 2008. [Online]. Available: <http://EconPapers.repec.org/RePEc:zbw:zewdip:7414>
- [10] M. Osborne and A. Rubinstein, *A Course in Game theory*. MIT Press, 1994.
- [11] J. Nash, "Two-person cooperative games," *Econometrica: Journal of the Econometric Society*, pp. 128–140, 1953.