When free riding is the best choice: the case of network charges for content providers

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***Abstract*—Content providers are often accused of free riding by exploiting the network to distribute their content without sharing their revenues with the network providers. In order to assess the correctness of such an accusation, we set up a game-theoretical model, where content providers releasing their contents for free and under the payment of a usage-based charge are both present. In this model, the network provider charges both content providers a usage-based charge (network charge) as well. The network provider and the paid content provider act as the players, using the respective retail prices as strategic leverages. Both the cases where network charges are set by the network provider and by a regulatory authority are examined. The Nash equilibrium is determined in a closed form. In a typical scenario, the solution represented by zero network charges maximizes both the network provider's revenues and the social welfare: free riding for content providers appears as the best choice under both the viewpoints of the selfish network provider and the regulatory authority.**

I. Introduction

Content providers distribute their content to end customers by exploiting the services of a network provider. However, while costs fall on the shoulders of network providers, payments for content benefit content providers only, building a gap difficult to sustain. Whatever the business model of content providers, they appear as free riders. Time and again, the pressure mounts on regulatory authorities to introduce network charges for content providers, so that the network provider may share a slice of their business success [1] [2]. On the other hand, vanishingly low prices for Internet connectivity compared to the wholesale prices commonly seen for the exchange of circuit-switched voice are credited for the good performance of the Internet market [3].

Several issues end up being interrelated with the network charging issues. Content providers who rely exclusively on advertising revenues for their economic survival (since they do not charge their customers directly) may find at a disadvantage as they are not able to offload their network charges on the end customer. On the other hand, content providers may circumvent the constraints imposed by network charges by charging their end customers, a practice known as *side payments* [4]. Furthermore, the network provider may apply different charges to content providers, favouring one or another. Such a partial behaviour represents a violation of the net neutrality principle [5] and hints at the possibility of collusion in the case of vertical integration [6]. Such a contrast between network and content provider is not new [7]: determining if network charges have to be applied and who has to set them is therefore a relevant problem.

Several attempts to analyze the issue have been made in the recent past. When the connection to the end customer is warranted by a chain of two ISPs (a transit ISP and a local one), and the content provider relies just on advertising and does not charge end customers, the issue of which ISP should charge content providers has been studied in [8], with a competition based on transport prices and results that depend on advertising rates. In [9], only one (pay-per-use) content provider has been considered, reaching the conclusion that ISPs are right to ask for a fairer share of the overall revenues, but that this cannot be achieved through side payments. In [10], [11], the need to arrive at revenue sharing rules among stakeholders has been stated, with side-payments considered as a tool to reach such a sharing agreement. A study of the interactions between a single content provider and the network provider with usage-based prices and a linear additive demand model has been conducted in [12] in a net neutrality context. The issue of net neutrality has again been considered in [13], where the ISP gains by charging a content provider for preferential access to its customers over other content providers, with all content providers distributing their contents for free. In [14], a game theoretic model has been proposed to analyse the impact of network charges on content providers' business model.

In this paper, we adopt the game-theoretic model we have previously proposed in [14] to analyse instead the strategy of network providers. Despite the aggressive attitude shown in the commercial world against content providers, it remains to be seen if levying a network charge is actually the optimal choice. We consider a context where content providers offering their services for free or under a side payment are both present (unlike in [9], where just one content provider is considered), and network charges may be either set by the regulatory authority or freely determined by the network provider to maximize its revenues (unlike in [8], where just the case of freely determined transport prices is considered). A multiplicative (rather than additive) expression of the demand function is employed with respect to previous attempts in the literature to take into account the depressive impact of transport prices on the customer's demand. We provide a closed form expression for the solution of the game. By applying the model

ISBN 978-3-901882-53-1, 9th CNSM 2013: Workshop ICQT 2013

to a typical scenario, we find that both the network provider's revenue and the social welfare are maximized when transport prices are zero, so that free riding is the best choice in that case.

The paper is organized as follows. We describe the stakeholders and their interactions In Section II, propose the game-theoretical model and solve it in Section III. In Section IV, we show an application of the model to a typical scenario.

II. A MODEL FOR THE INTERACTIONS BETWEEN SERVICE PROVIDERS AND CUSTOMERS

Contents reach the customer through a chain of services, which carry along economic relationships. In this section, we provide an essential model of such services. We first define the stakeholders and then describe how money is exchanged for services in the various rings of the chain.

Let's start by defining who's involved in the overall service provisioning by referring to the scheme shown in Fig. 1. On the top of the picture, we see two content providers, which embody the two breeds: those that deliver contents for free and those that require a payment. The content provider of the first kind is identified as provider F, while the provider of paid contents is P. The market is crowded with content providers that may differ for several aspects: larger, global providers may exert a greater power, as opposed to providers operating on a smaller, regional scale or offering a limited set of service. However, within each market segment (e.g., a regional market, or a content niche), we end up with providers basically differing for their business model, offering services for free or on a paid basis, as in Fig. 1. An example of such a competition between content provider is the delivery of TV series by YouTube versus the same service offered through subscription or on a pay-per-use basis through VoD or IPTV.

Both providers need to reach the customer through the network and rely on the network provider N, which in turn provides the final connection to the customer U. We consider a monopolistic network provider as a realistic model of the actual situation. In fact, access is a natural monopoly, since the access infrastructure is not easily replicable. Though the access market may appear to have an oligopolist structure in real markets, this is due to a tight enforcement by the regulatory authority: the access infrastructure is often owned by a single provider, that is forced to lease it to other providers at a regulated price. Competition at the access level may be more apparent (as an artifact of regulatory pressure) than real.

At each stage in the chain some payment is provided. In the following we assume that all payments are proportional to the amount of data delivered. The two content providers rely on advertising in their business model. Unit revenues are v_F and v_P respectively. The free content provider has no additional revenues: its business model relies totally on advertising to recover costs and make a profit. Instead, the paid content provider also receives a payment from the customer, who pays a price p_S for each unit of data delivered. Without loss of generality, we may assume in the following that data are measured in Gigabytes (GB), so that all the prices are expressed in €/GB. Content providers pass their data to the network provider, which charges them for transport, with unit prices respectively t_F and t_P. Transport prices may be set freely or determined by the regulator. The latter possibility is a reality in current markets, since wholesale prices (for telephony or for bistream data) are often either dictated or at least approved by the regulator. The condition $t_F = t_P$ corresponds to a neutral behaviour by the network provider, since both content providers are treated equally by the network provider. The imbalance $t_F \neq t_P$ instead brings along a preferential treatment of one content provider with respect to the other (hence, a non-neutral behaviour). Finally, the customer pays both the network provider and the paid content provider. We have already introduced the payment to P. The payment to the network provider is p_{N} for each unit of data delivered.

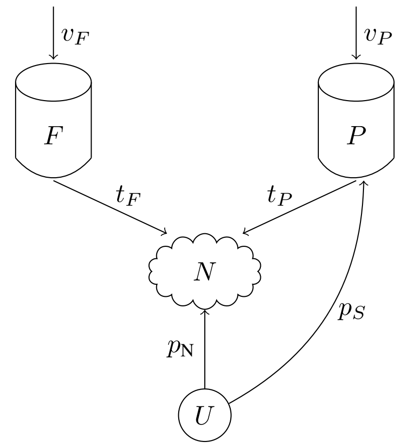

Fig. 1. Flows of payments. All prices are unitary.

III. STRATEGIC PRICING FOR CONTENT AND NETWORK PROVISIONING

In Section II, we have described a model where four stakeholders interact: two content providers, the network provider, and the customer. In addition to those explicitly appearing in the model depicted in Fig. 1, the regulator enters the picture. The leverages that determine the interaction are the transport prices (differentiated for the two content providers), the retail prices, and the customer's demand. In order to assess the outcome of that interaction, we have to define who sets what. In this section, we identify the roles played by the stakeholders, describe their interaction through a game model, and show how that model can be solved to reach an equilibrium representing the rational outcome of the interaction.

We start by describing the roles played by the stakeholders. Both content providers derive their income from advertising, on which they have no influence. However, the paid content provider can modulate its overall revenues by acting on the retail price p_S, while the free content provider has no leverage at all. Both content providers are subject to network charges, through the transport prices. The free content provider is therefore a sheer *price taker*. The paid content provider can use the retail price p_S as its strategical leverage. On the other extreme of the service chain, we find the customer, who is subject to charging by both the network provider and the paid content provider. The customer acts as a price taker and can react just by modifying its consumption, as embodied by its demand function. In between, the network provider could act on both the retail price p_{N}, charged to the customer, and the transport prices, charged to content providers. Here we assume that the network provider can act freely on just the retail price; the transport prices are instead ultimately set by the regulatory body. Summing up, we have two key players, the paid content provider and the network provider, employing as strategical leverages their respective retail prices.

The service consumption is regulated by the demand function of the customer. We consider that the customer's demand is different for free and paid services. The demand is assumed to depend on prices (both the retail and the transport ones) and includes cross-effects: the customer will shift to free contents if the price for paid ones increases, and vice versa. We include the effect of transport prices because content providers are less keen to provide their contents if their profit margin reduces, which in turn cools down demand (since less contents are available). As to the shape of the dependence of demand on prices, we adopt a linear multiplicative model instead of an additive one, as done in [12] and [5]. Our choice has the advantages of removing additional constraints on the demand function's domain, since the demand is naturally bounded between 0 and its maximum value, and accounting separately for the different factors influencing demand. In addition, accounting for a positive cross-elasticity is more easily done with a multiplicative rather than additive model. The resulting demand functions for free and paid contents are respectively

$$\begin{aligned} D_{\mathrm{F}} &= \frac{D_{\mathrm{F}}^*}{1+\alpha}\left(1-\frac{t_{\mathrm{F}}}{v_{\mathrm{F}}}\right)\left(1+\alpha\frac{p_{\mathrm{S}}}{p_{\mathrm{S}}^*}\right)\left(1-\frac{p_{\mathrm{N}}}{p_{\mathrm{N}}^*}\right), \\ D_{\mathrm{P}} &= D_{\mathrm{P}}^*\left(1-\beta\frac{t_{\mathrm{P}}}{v_{\mathrm{P}}}\right)\left(1-\frac{p_{\mathrm{S}}}{p_{\mathrm{S}}^*}\right)\left(1-\frac{p_{\mathrm{N}}}{p_{\mathrm{N}}^*}\right). \end{aligned} \tag{1}$$

The values D_{F}^* and D_{P}^* mark the maximum usage the customer would attain, even if the prices should drop to zero. The demand for free contents zeroes if either the retail price paid to the network provider reaches the maximum tolerable value p_{N}^* (the *willingness-to-pay* for network access) or the transport price charged to the free content provider erodes completely the advertising revenues. In addition to the condition on the transport price and the retail price paid to the network provider, the demand for paid contents zeros also if the retail price paid to the paid content provider reaches the maximum tolerable value p_{S}^* (the *willingness-to-pay* for paid contents). The demand functions (15) incorporate also the cross-effects of prices: if the retail price for paid contents grows, the demand moves towards free contents. On the other hand, the coefficient β modulates the impact of the transport price for paid contents on the demand for the same contents. We have $\beta < 1$ since, even when the transport price absorbs completely the advertising revenues ($t_{\mathrm{P}} = v_{\mathrm{P}}$), the paid content provider has still an incentive to provide contents due to the fare p_{S} charged to end customers. We can compute the cross-elasticity of the demand for free contents with respect to the retail price, which represents the percentage change in the demand for each unit percent change in the retail price p_{S}

$$\varepsilon_{p_{\mathrm{S}}} = \frac{p_{\mathrm{S}}}{D_{\mathrm{F}}}\frac{\partial D_{\mathrm{F}}}{\partial p_{\mathrm{S}}} = \frac{\alpha p_{\mathrm{S}}/p_{\mathrm{S}}^*}{1+\alpha p_{\mathrm{S}}/p_{\mathrm{S}}^*}. \tag{2}$$

As expected, the cross-elasticity is positive (the demand for free contents and the retail price by the paid content provider move in the same direction, unlike in [4]), but lower than unity.

The revenues of the content providers and the network provider are easily built from Fig. 1:

$$\begin{aligned} R_{\mathrm{F}} &= D_{\mathrm{F}}(v_{\mathrm{F}} - t_{\mathrm{F}}), \\ R_{\mathrm{P}} &= D_{\mathrm{P}}(v_{\mathrm{P}} + p_{\mathrm{S}} - t_{\mathrm{P}}), \\ R_{\mathrm{N}} &= D_{\mathrm{F}}t_{\mathrm{F}} + D_{\mathrm{P}}t_{\mathrm{P}} + p_{\mathrm{N}}(D_{\mathrm{F}} + D_{\mathrm{P}}). \end{aligned} \tag{3}$$

For the customer, we can compute its surplus, computed, as customary, as the difference between its willingness-to-pay and the actual price, integrated over the actual demand range (i.e., the area of a triangle below the demand curve, which accounts for the factor 2 appearing in the final expression):

$$R_{\mathrm{U}} = \frac{D_{\mathrm{F}}(p_{\mathrm{N}}^* - p_{\mathrm{N}}) + D_{\mathrm{P}}(p_{\mathrm{S}}^* - p_{\mathrm{S}})}{2}. \tag{4}$$

As stated earlier, we can now formulate a game between the paid content provider and the network provider, where the leverages are their respective retail prices and the aim is to maximize their respective revenues. In order to solve the game and find the optimal values for the strategic variables, we look first for the best response function. We recall that, in a two-player game, the best-response function of player i is the function $Z_i(a_j)$ that, for every given action a_j of player j, assigns an action $a_i = Z_i(a_j)$ that maximizes player i 's payoff $\Pi_i(a_i, a_j)$. In our case, the actions taken by the two players consist in setting the prices p_{S} and p_{N}, so that their best response functions are

$$\begin{aligned} \hat{p}_{\mathrm{S}} &= \underset{p_{\mathrm{S}}}{\operatorname{argmax}}\{R_{\mathrm{P}}(p_{\mathrm{N}}, p_{\mathrm{S}}, v_{\mathrm{F}}, v_{\mathrm{P}}, t_{\mathrm{F}}, t_{\mathrm{P}}, p_{\mathrm{N}}^*, p_{\mathrm{S}}^*, D_{\mathrm{F}}^*, D_{\mathrm{P}}^*, \alpha, \beta)\}, \\ \hat{p}_{\mathrm{N}} &= \underset{p_{\mathrm{N}}}{\operatorname{argmax}}\{R_{\mathrm{N}}(p_{\mathrm{N}}, p_{\mathrm{S}}, v_{\mathrm{F}}, v_{\mathrm{P}}, t_{\mathrm{F}}, t_{\mathrm{P}}, p_{\mathrm{N}}^*, p_{\mathrm{S}}^*, D_{\mathrm{F}}^*, D_{\mathrm{P}}^*, \alpha, \beta)\}. \end{aligned} \tag{5}$$

By applying those definitions to the revenues reported in Equation (3), we obtain the following best response functions (the detailed derivation is reported in the Appendix):

$$\begin{aligned} \hat{p}_{\mathrm{S}} &= p_{\mathrm{S}} : \left\{\frac{\partial R_{\mathrm{P}}}{\partial p_{\mathrm{S}}} = 0\right\} = \frac{p_{\mathrm{S}}^* + t_{\mathrm{P}} - v_{\mathrm{P}}}{2}, \\ \hat{p}_{\mathrm{N}} &= p_{\mathrm{N}} : \left\{\frac{\partial R_{\mathrm{N}}}{\partial p_{\mathrm{N}}} = 0\right\} \\ &= \frac{p_{\mathrm{N}}^*}{2}\frac{D_{\mathrm{F}}^*\Lambda\left(1 - t_{\mathrm{F}}/p_{\mathrm{N}}^*\right) + D_{\mathrm{P}}^*(1+\alpha)\Upsilon\left(1 - t_{\mathrm{P}}/p_{\mathrm{N}}^*\right)}{D_{\mathrm{F}}^*\Lambda + D_{\mathrm{P}}^*(1+\alpha)\Upsilon}, \end{aligned} \tag{6}$$

where we use the following positions to simplify the expression

$$\begin{aligned} \Lambda &= \left(1-\frac{t_{\mathrm{F}}}{v_{\mathrm{F}}}\right)\left(1+\alpha\frac{p_{\mathrm{S}}}{p_{\mathrm{S}}^*}\right), \\ \Upsilon &= \left(1-\beta\frac{t_{\mathrm{P}}}{v_{\mathrm{P}}}\right)\left(1-\frac{p_{\mathrm{S}}}{p_{\mathrm{S}}^*}\right). \end{aligned} \tag{7}$$

We notice that: a) the optimal retail price for the paid content provider does not depend on the network provider's choice (hence, that is a dominant strategy); b) it is the arithmetic mean of the customer's willingness-to-pay and the excess transport price $t_{\text{P}} - v_{\text{P}}$; c) the optimal retail price for the network provider is lower than half the customer's willingness-to-pay.

After having derived the best response functions, we can look for the presence of a Nash equilibrium, defined as the solution of the game for which the two best response functions in Equation (5) meet.

The solution of the game is obtained by simply replacing the first of Equations (5) into the second. On the (p_{S},p_{N}) plane, the first of Equations (5) is represented by a straight line, while the optimal price set by the network provider is a monotone function of the price set by the paid content provider. The equilibrium solution, representing the rational outcome of the game is the point ($\hat{p}_{\text{S}}$,$\hat{p}_{\text{N}}$):

$$\begin{aligned} \hat{p}_{\text{S}} &= \frac{p_{\text{S}}^* + t_{\text{P}} - v_{\text{P}}}{2}, \\ \hat{p}_{\text{N}} &= \frac{p_{\text{N}}^*}{2} \frac{D_{\text{F}}^* \Lambda^* \left(1 - t_{\text{F}}/p_{\text{N}}^*\right) + D_{\text{P}}^* (1+\alpha) \Upsilon^* \left(1 - t_{\text{P}}/p_{\text{N}}^*\right)}{D_{\text{F}}^* \Lambda^* + D_{\text{P}}^* (1+\alpha) \Upsilon^*}, \end{aligned} \tag{8}$$

where

$$\begin{aligned} \Lambda^* &= \left(1 - \frac{t_{\text{F}}}{v_{\text{F}}}\right) \left[1 + \frac{\alpha}{2} \left(1 + \frac{t_{\text{P}} - v_{\text{P}}}{p_{\text{S}}^*}\right)\right], \\ \Upsilon^* &= \frac{1}{2} \left(1 - \beta \frac{t_{\text{P}}}{v_{\text{P}}}\right) \left(1 + \frac{v_{\text{P}} - t_{\text{P}}}{p_{\text{S}}^*}\right). \end{aligned} \tag{9}$$

This solution is valid if both the following inequalities hold

$$\begin{aligned} 0 &< \hat{p}_{\text{S}} < p_{\text{S}}^*, \\ 0 &< \hat{p}_{\text{N}} < p_{\text{N}}^*. \end{aligned} \tag{10}$$

When both content providers are allowed free riding, the net neutrality principle is also satisfied, since $t_{\text{F}} = t_{\text{P}} = 0$. In this case, both the network provider and the paid content providers set their prices without strategic interactions with each other. By considering zero transport prices in Equation (8), the prices resulting as a Nash equilibrium of the game are

$$\begin{aligned} \hat{p}_{\text{S}} &= \frac{p_{\text{S}}^* - v_{\text{P}}}{2}, \\ \hat{p}_{\text{N}} &= \frac{p_{\text{N}}^*}{2} \frac{D_{\text{F}}^* \Lambda^* + D_{\text{P}}^* (1+\alpha) \Upsilon^*}{D_{\text{F}}^* \Lambda^* + D_{\text{P}}^* (1+\alpha) \Upsilon^*} = \frac{p_{\text{N}}^*}{2}. \end{aligned} \tag{11}$$

We notice that under free riding the network provider's strategy too is a dominant one. By replacing that result in Equation (3), we obtain the revenues for the network provider

$$R_{\text{N}} = \frac{p_{\text{N}}^*}{8} \left[D_{\text{F}}^* \frac{2+\alpha}{1+\alpha} + D_{\text{P}}^* + \frac{v_{\text{P}}^*}{p_{\text{S}}^*} \left(D_{\text{P}}^* - D_{\text{F}}^* \frac{\alpha}{1+\alpha}\right)\right]. \tag{12}$$

So far, the rational choice for the network provider has been determined as the outcome of a game, where the network provider sets its retail price. However, the actual price provided by the game depends on the transport prices. In the absence of constraints, a natural choice for the network provider is to set transport price so as to maximize its revenues. This would put it to a remarkable advantage over content providers, endowing it with three leverages (the retail price and two transport price) at its disposal. Such excess power may not be desirable from a social perspective. In this section, we envisage a regulatory intervention on transport prices.

Alternatively, transport prices are not freely set by the network provider but are imposed by the regulatory authority, which may act according to two inspiring principles: 1) taking care of the interests of stakeholders on the overall; 2) granting a fair treatment to the two content providers.

The first principle can be complied with by setting transport prices so as to maximize the social welfare W, given by the sum of the revenues (surpluses) of all the stakeholders

$$W = R_{\text{F}} + R_{\text{P}} + R_{\text{N}} + R_{\text{U}}. \tag{13}$$

The second principles calls instead for equal transport prices, so that $t_{\text{F}} = t_{\text{P}}$. This principle may be of particular concern when the network provider has some vested interest in the operations of either content provider. For example, if a vertical integration is at work with the paid content provider, the network provider may be led to set $t_{\text{F}} > t_{\text{P}}$ to squeeze profits out of the free content provider. When the condition of net neutrality is imposed, the Nash equilibrium point is obtained by setting $t_{\text{F}} = t_{\text{P}} = t$ in Equations (8):

$$\begin{aligned} \hat{p}_{\text{S}} &= \frac{p_{\text{S}}^* + t - v_{\text{P}}}{2}, \\ \hat{p}_{\text{N}} &= \frac{p_{\text{N}}^*}{2} \left(1 - \frac{t}{p_{\text{N}}^*}\right) = \frac{p_{\text{N}}^* - t}{2}. \end{aligned} \tag{14}$$

In this case the transport price has an opposite symmetric (and linear) effect on the retail prices of the content provider and network provider. The impact on the demand remains instead remarkably unsymmetric and non linear, as can be seen by replacing Equations (14) in the demand functions of Equations (15):

$$\begin{aligned} D_{\text{F}} &= \frac{D_{\text{F}}^*}{1+\alpha} \left(1 - \frac{t}{v_{\text{F}}}\right) \left(1 + \frac{\alpha}{2} + \alpha \frac{t - v_{\text{P}}}{2p_{\text{S}}^*}\right) \left(\frac{1}{2} + \frac{t}{2p_{\text{N}}^*}\right), \\ D_{\text{P}} &= D_{\text{P}}^* \left(1 - \beta \frac{t}{v_{\text{P}}}\right) \left(\frac{1}{2} + \frac{v_{\text{P}} - t}{2p_{\text{S}}^*}\right) \left(\frac{1}{2} + \frac{t}{2p_{\text{N}}^*}\right). \end{aligned} \tag{15}$$

IV. A SAMPLE CASE

In Section III, we have shown how the game between the paid content provider and the network provider can be solved to obtain the retail prices. We have now all the tools to determine the complete set of prices. In this section, we apply those tools to a typical scenario and examine the results.

We consider the scenario described in Table I. Those values have been set on the basis of data gathered on the market. The value for β is representative of a significant influence of transport prices on the demand: when the transport prices zero advertising revenues, the demand halves.

Since transport prices can be set in several ways, we consider first the case where they are set by the regulatory authority to maximize the social welfare. We plot in Fig. 2

Parameter	Value
p_N^*	3.67 €/GB
p_S^*	3.23 €/GB
D_F^*	20.62 GB/month
D_P^*	30.94 GB/month
v_F	0.5 €/GB
v_P	0.2 €/GB
α	1
β	0.5

TABLE I. PARAMETERS' VALUES FOR THE REFERENCE SCENARIO

the social welfare as a function of the normalized transport price $t_\mathrm{P}/v_\mathrm{P}$ for the paid content provider. The social welfare decreases as the transport price increases. The decline is quite remarkable, since exploiting the full range of the transport price leads the social welfare to a sharp downfall, by 25.1% when $t_\mathrm{F} = 0$ and by 42.8% when $t_\mathrm{P}/v_\mathrm{P} = 0.75$. Since the decline accelerates when the transport price is increased for the free content provider as well, we can conclude that both transport prices bear negative consequences on the social welfare. In Fig. 3, we consider instead the dependence on the

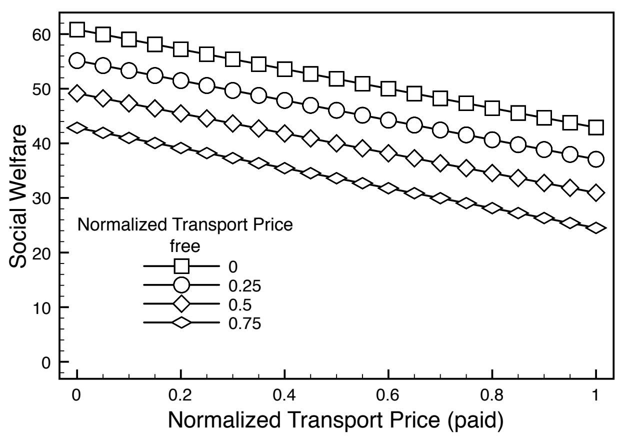

Fig. 2. Social welfare vs transport prices for paid content

transport price paid by the free content provider. Again, we observe a monotone decreasing trend, with a steeper slope than that observed in Fig. 2. The optimal choice for the regulatory authority is then to favour the bill-and-keep approach, since that maximizes the social welfare. This satisfies at the same time the principle of neutrality, since both prices are equal.

If we allow the network provider to set its transport prices regardless of any regulatory imposition, we must look for those prices that maximize its revenues. In Fig. 4 and Fig. 5, we plot the relationship between the revenues and the transport prices. We see that the trend is declining in both cases: due to the depressing effect on demand, increasing transport prices leads to decreasing revenues for the network provider. The optimal solution for the network provider is therefore again to allow free riding. The reason for such a trend is that increasing transport prices weakens the demand for services and depresses the usage values that fuel the network provider's revenues.

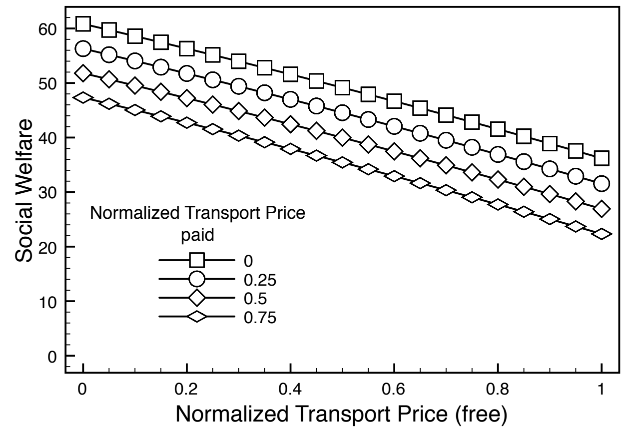

Fig. 3. Social welfare vs transport prices for free content

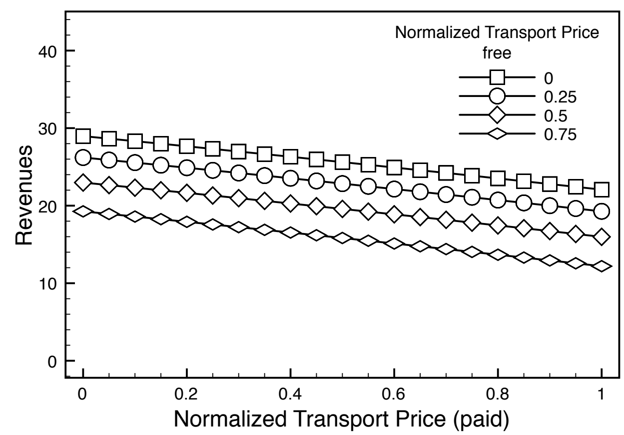

Fig. 4. Network provider's revenues vs transport prices for paid content

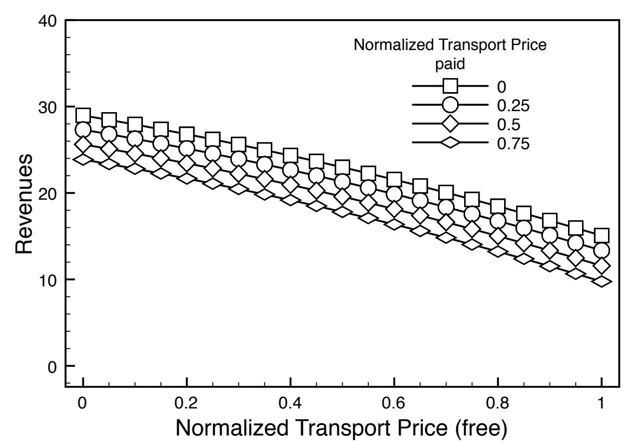

Fig. 5. Network provider's revenues vs transport prices for free content

V. Conclusion

The issue of network charging for content providers has to be analyzed by considering all the stakeholders involved. Content providers may be constrained by network providers if the latter is free to determine transport prices, especially if the content provider relies just on advertising revenues. We have set up a game-theoretic model for a context where both a free and a paid content providers act and a regulatory authority may intervene to regulate transport prices. In the game, the paid content provider and the network provider employ the retail price as a strategic leverage. For that model, we provide the solution of the game in closed form and analyse both cases, where transport prices are set either by the network provider to maximize its revenues or by the regulatory authority to maximize the social welfare. For a typical scenario, we find that in both cases the rational outcome of the game leads to zero transport prices for both content providers. What is usually named as free riding (since content providers do not pay an additional fee to the network provider for the content they provide) appears as the most convenient solution.

Appendix
Derivation of the best response functions

The best response functions of the paid service provider and the network providers are obtained by maximizing their respective surplus functions with respect to their leverage (their retail prices). We start with the paid content provider by zeroing the derivative of the surplus function. By recalling the second expression in Equation (3), we have

$$\frac{\partial R_{\mathrm{P}}}{\partial p_{\mathrm{S}}} = \frac{\partial D_{\mathrm{P}}}{\partial p_{\mathrm{S}}}(v_{\mathrm{P}} + p_{\mathrm{S}} - t_{\mathrm{P}}) + D_{\mathrm{P}} = 0 \tag{16}$$

By replacing the second expression in Equation (15) for the demand function of the paid content provider, Equation (16) becomes

$$\begin{aligned} &D_{\mathrm{P}}^{*}\left(1-\beta\frac{t_{\mathrm{P}}}{v_{\mathrm{P}}}\right)\left(-\frac{1}{p_{\mathrm{S}}^{*}}\right)\left(1-\frac{p_{\mathrm{N}}}{p_{\mathrm{N}}^{*}}\right)(v_{\mathrm{P}}+p_{\mathrm{S}}-t_{\mathrm{P}}) \\ &\quad +D_{\mathrm{P}}^{*}\left(1-\beta\frac{t_{\mathrm{P}}}{v_{\mathrm{P}}}\right)\left(1-\frac{p_{\mathrm{S}}}{p_{\mathrm{S}}^{*}}\right)\left(1-\frac{p_{\mathrm{N}}}{p_{\mathrm{N}}^{*}}\right)=0, \end{aligned} \tag{17}$$

which may be simplified to

$$-\frac{v_{\mathrm{P}} + p_{\mathrm{S}} - t_{\mathrm{P}}}{p_{\mathrm{S}}^{*}} + 1 - \frac{p_{\mathrm{S}}}{p_{\mathrm{S}}^{*}} = 0, \tag{18}$$

whose solution for the retail price is

$$p_{\mathrm{S}} = \frac{p_{\mathrm{S}}^{*} + t_{\mathrm{P}} - v_{\mathrm{P}}}{2}. \tag{19}$$

As to the best response function of the network provider, we maximize its surplus by zeroing its derivative with respect to its retail price and recalling the third expression in Equation (3) :

$$\frac{\partial R_{\mathrm{N}}}{\partial p_{\mathrm{N}}} = (t_{\mathrm{F}}+p_{\mathrm{N}})\frac{\partial D_{\mathrm{F}}}{\partial p_{\mathrm{N}}} + (t_{\mathrm{P}}+p_{\mathrm{N}})\frac{\partial D_{\mathrm{P}}}{\partial p_{\mathrm{N}}} + D_{\mathrm{F}} + D_{\mathrm{P}} = 0. \tag{20}$$

By replacing the expressions in Equation (15) for the two demand function, using the positions in Equation (7), and gathering common terms, we have

$$\begin{aligned} &\frac{D_{\mathrm{F}}^{*}\Lambda}{1+\alpha}\left(1-\frac{p_{\mathrm{N}}+t_{\mathrm{F}}}{p_{\mathrm{N}}^{*}}\right)+D_{\mathrm{P}}^{*}\Upsilon\left(1-\frac{p_{\mathrm{N}}+t_{\mathrm{P}}}{p_{\mathrm{N}}^{*}}\right) \\ &-p_{\mathrm{N}}\left[\frac{D_{\mathrm{F}}^{*}}{p_{\mathrm{N}}^{*}(1+\alpha)}\Lambda+\frac{D_{\mathrm{P}}^{*}}{p_{\mathrm{N}}^{*}}\Upsilon\right]=0. \end{aligned} \tag{21}$$

By rearranging terms and solving for the retail price p_{N}, we finally get

$$p_{\mathrm{N}} = \frac{p_{\mathrm{N}}^{*}}{2}\frac{D_{\mathrm{F}}^{*}\Lambda\left(1-t_{\mathrm{F}}/p_{\mathrm{N}}^{*}\right)+D_{\mathrm{P}}^{*}(1+\alpha)\Upsilon\left(1-t_{\mathrm{P}}/p_{\mathrm{N}}^{*}\right)}{D_{\mathrm{F}}^{*}\Lambda+D_{\mathrm{P}}^{*}(1+\alpha)\Upsilon}. \tag{22}$$

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