International Journal of Engineering & Technology, 7 (2.28) (2017) 176-180

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

The governance of Internet and game theory

Olivier Lefebvre

Olivier Lefebvre Consultant 4 rue Rollin 75005 Paris France
**Corresponding author E-mail: o.lefebvreparis05@orange.fr*

Abstract

The professional milieu of telecommunications is livened up by controversies lasting decades. The controversy about access charges (or termination rates, the price paid by an operator to another when the subscriber's call ends on its network) is ending, while the controversy about Net neutrality is starting. The article focuses on a "fragment": the regulator's action. Game theory is useful to answer two questions: (1) why does the regulator decide the decrease and cancellation of access charges (justification)? (2) How does he do it (tactical feasibility)? When the access charges decrease and are cancelled the retail prices decrease and the consumers' surplus increases. And concerning the tactical feasibility, the regulator can let untouched the profits when he decides some decrease of the access charges (direct effect), then the retail prices decrease when there is a new Nash equilibrium (strategic effect). The operators cannot protest, neither during the first stage (the profits are untouched) neither during the second stage (it would be to admit that access charges are useful to have higher profits thanks to high retail prices, which is detrimental to consumers).
One brings some explanation of the move towards access charges lowered or cancelled. Examples are: (1) the peering in the governance of Internet and (2) what is called the Eurotariff (for instance, roaming charges for users of mobile phones in Europe have been cancelled).

Keywords*: Game Theory; Internet Governance; Regulation; Telecommunications.*

1. Introduction.

This article is about "access charges". Access charges are the payments that operators make when the calls of their customers are carried by other operators [1]. It concerns Internet, mobile telephony (voice, data, Short Messages) and fixed telephony. They can exist or not. When the call terminations are not paid for it is called "peering" [2] or "keep and forget". It means that an operator pays for nothing when the calls of its customers are carried by another operator, and it carries the calls of the other operators for free (it is called the "potato" in the jargon of telecommunications and it is in more accurate words an easement). From the start the governance of Internet is based upon peering. And a slow but compelling move towards peering has started in the field of telephony. Anywhere the regulators decide to decrease and cancel the access charges. Now they are of a small amount or have been cancelled. There are sometimes access charges when small operators are concerned, because there is some quarrel between them (for instance, one claims that the quality of service of the other is bad).
What explanation can be given?
One refers to the notion of "economies of atmosphere" set out by the American economist O Williamson in his book "The economic institutions of the capitalism" [3]. Some decisions are possible or not, at some time, given the "atmosphere". For instance, during the Middle Ages, in Europe, there was a development of windmills because it was more difficult for the lords to tax them than to tax watermills. Notice that today to tax what is in the air (the waves) is possible, since the State does it. But in the Middle Ages, the lords who were able to tax the water were unable to tax the wind [3]. Concerning the decrease and cancellation of access charges, it is part of a pack of measures: privatization, regulation, Net neutrality and cancellation of access charges. The move starts with the famous Consent Decree of the judge Greene in the USA in 1982, which launched competition in the telecommunications sector. In Europe there was the active role of the German commissar Martin Bangeman when the "Bangeman Report" was published, in 1994. Finally these measures are more or less applied anywhere. The country where the move has started, the USA, has benefitted from them. The measures allow the circulation of huge quantities of data on the networks, the consumers paying the lowest price which is possible. And the American firms called GAFAM (Google, Apple, Facebook, Amazon and Microsoft) have become leaders in the world thanks to networks allowing the sale of contents to the consumers. The access charges have decreased or have been cancelled because they are supposed to be useful to operators to gain more revenues, while the retail prices are higher. It is detrimental to consumers.
But how game theory could be used to obtain more explanations?
In this article one argues that game theory can be useful to explain these three points:
It confirms that when regulators decrease or cancel access charges the consumers' surplus increases. Also, the total surplus, considered in the two countries (or continents) which are concerned increases.
It is better if the regulator acts at a larger scale. The argument that the total surplus in the two countries which are concerned by the traffic (or the two continents) increases, holds only if there is a single regulator in these two countries (or continents). Otherwise, the only argument (justifying the decrease and cancellation of access charges) is the increase of the consumers 'surplus in each country. Possibly, the total surplus increases in the two countries

Copyright © 2016 Authors. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

but decreases in one and increases in the other. And it is not sure that a regulator in a country can cancel the access charges gained by the operators in this country if the access charges paid by these operators are not cancelled (because the regulator in the other country does not decide it). Examples of regulators acting at a large scale are ISOC (Internet Society) when Internet is concerned, and the European Parliament. A few years ago the European Parliament voted a law to cancel access charges in mobile telephony (at least when roaming is concerned) in the countries of European Union[1]. Today they are at a very low level or cancelled.

The move is tactically feasible. Here one uses the distinction between direct effect and strategic effect, brought by game theory. The regulator can obtain the decrease of retail prices in two stages: (1) he decreases the access charges in such a way that the profits of the operators are not changed (2) because of the strategic effect, the operators decrease their prices. It is tactically feasible because the operators cannot protest against the decision. Their profits remain untouched (direct effect). But because of the strategic effect they could decrease. However, if they protest against the regulator's decision, arguing that their profits will decrease when the prices will decrease (strategic effect) they admit that access charges are useful to increase the operators' revenues. And it is detrimental to consumers since access charges trigger higher prices.

To demonstrate these three points thanks to game theory one models four cases:

Case 1: in each country (continent) there is a monopoly selling traffic towards the other country. This case is the simplest (of the four) and it is easy to deal with it.

Case 2: in each country there are two operators selling traffic towards the other country. They are competitors. To deal with this case is not very easy, so one considers the symmetrical case (all the costs are equal, the demands are the same).

Case 3: like when Internet traffic is concerned, one considers a large operator (tier 1) carrying the traffic of several local operators (tier 2). One takes into account the aggregate demand of the operators of the tier 2.

Case 4: It is the case of two operators in the same country, competitors and connected, both. It is very easy to see that in ordinary conditions … nothing happens (there is no effect of access charges). But if one takes into account the "club effect" (one of the operators allows rebates to its customers when they call one another) the access charges have a role. One models the "club effect".

The plan of the article is the following: remarks on the method (the topic of existing literature is dealt with); Case 1; Case 2; Case 3; Case 4 and Conclusion.

2. Remarks on the method.

The demand for the traffic towards the other country is noted D_i, any function positive, decreasing, differentiable and concave. One does not take into account a "network effect" that is to say the increase of demand if the demand in the other country increases (D_i (p_i, q_j), $\partial D_i / \partial q_j > 0$). Indeed, if there is a "generation effect" there is also a "substitution effect" and the sum of the two effects is not known. One can quote many examples of "substitution effect":

There is a problem to solve. For instance, E_1 is the customer of a carrier E_2 and there is some problem to solve. If N calls are needed, if E_1 calls E_2 n_1 times, and E_2calls E_1 n_2 times, $N = n_1 + n_2$. If n_1 increases, n_2 decreases.

There is an obligation. If there is an obligation for somebody to speak with another person N times a year, if this person calls, the first person calls less.

An unwelcome person calls. Of course, in this case the called person makes no call.

Etc.

At the opposite of Baranes and Jeanneret in their article (which deals with the topic of access charges using game theory) [4], one does not take into account network effect.

Now one deals with the topic of existing literature. The topic of access charges has been often dealt with, diverse hypotheses being made and with diverse results. For instance one takes into account the network externalities (communication generates communication), particular tariffs, the competition between mobile telephony and fixed telephony, the subsidization of the terminals, the discrimination between on net and off net calls, the case of Receiving Party Pays etc. The results are very diverse. In general one compares the welfare maximizing and the profit maximizing level of access charges. In this paper one presents simple cases, insisting on (1) the justification of the regulator (2) the tactical feasibility of the regulator's decision. Indeed, now the end of the story, concerning access charges, is known: anywhere they are disappearing or have disappeared. So it matters to explain the measures taken by the regulators and their effects.

A last remark on the method concerns the general approach of the four cases. It is the following:

One writes the profits of the operators

Deriving the profit one obtains the equations of the Nash equilibrium. One checks that the function of profit derived two times is negative (there is a single value maximizing the profit).

One states that the regulator can decide a decrease of the access charges which does not change the profits (direct effect).

One checks that after the decrease of the access charges the operators decrease the retail prices (strategic effect).

One comments on the consequences in terms of surplus (consumers' surplus, total surplus, profits of the operators).

One notes the demands D_i, the costs c_i, the profits $\prod_i$, the access charges π_i and the retail prices p_i.

3. Case 1: in each country a monopoly sells traffic towards the other country.

The profit $\prod_1$ is noted:

$\prod_1 = D_1 (p_1) (p_1 - c_1 - \pi_2) + (\pi_1 - c_1) \;\; D_2 (p_2)$ (1).

One does not write $\prod_2$, obtained by reversing the indices.

The gain of E_1 thanks to access charges is $\pi_1 D_2 - \pi_2 D_1$ and the gain of E_2, $\pi_2 D_1 - \pi_1 D_2$. One is winning and the other is losing. But it does not mean that the losing operator accepts the decrease and cancellation of access charges, since if they are cancelled, perhaps it gains less. If the regulator decreases the access charges in some way ($d\pi_1 / d\pi_2 = D_1 / D_2$), the profits are untouched.

The equations giving the Nash equilibrium are:

$$D'_1 (p_1) (p_1 - c_1 - \pi_2) + D_1 (p_1) = 0 \quad (2).$$

(The same for $\partial \prod_2 / \partial p_2 = 0$, which one obtains by reversing the indices).

The reaction function depends on p_1 only. When $d\pi_2 < 0$, it is moved towards the left. During the first move $\prod_1$ increases but it is a small quantity of second order. The reaction function of E_2 is moved downwards (p_2 decrease). During the second move $\prod_1$ increases if $\pi_1 - c_1 > 0$ and decreases if $\pi_1 - c_1 < 0$, but the quantity is of the first order. Finally $\prod_1$ increases if $\pi_1 - c_1 > 0$ and decreases if $\pi_1 - c_1 < 0$. At some time, when the regulator decreases the access charges the two quantities $\pi_i - c_i$ are negative. Therefore the two profits decrease.

On the figure 1, the equilibrium point moves from E to E'.

The consumers' surplus increases in each country. The total surplus in the two countries increases since one can neglect the flows of money because of the access charges, their sum being 0. That is why it is better if the regulator exists at the scale of the two countries (ISOC at the level of the world, the European Parliament

[1] Indeed, other European countries not in the European Union have followed the move.

in the European Union). In a single country it is not sure that the total surplus increases: the consumers 'surplus increases but the operator's profit should decrease and perhaps the sum could decrease.
The regulator can decrease the access charges gradually, step by step. If, for instance π_1 is equal to 0 and $\pi_2 > 0$, he can cancel π_2 because it is disloyal if E_1 pays access charges and not E_2. Or he can decrease π_2 gradually. The price p_1 decreases while the price p_2 remains constant. If the access charges are cancelled in one time, it is easy to prove that the two prices decrease. One uses: $\partial^2 \prod_i / \partial p_i^2 < 0$. If the access charges are decreased gradually it is tactically feasible. The profits are untouched when the access charges decrease (direct effect). Then the prices decrease and perhaps the profits decrease also. But if the operators protest, they admit that access charges are useful to increase the profits. It is thanks to higher prices, which is detrimental to consumers.

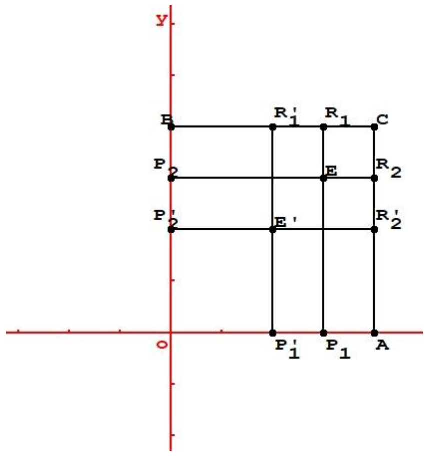

Figure 1. When the prices decrease the equilibrium moves from E to E'. The reaction function of E_1 is $P_1 R_1$ when the price is p_1 and $P'_1 R'_1$ when the price is p'_1. The reaction function of E_2 is $P_2 R_2$ when the price is p_2 and $P'_2 R'_2$ when the price is p'_2.

One easily demonstrates that $\pi_1 = c_1$ and $\pi_2 = c_2$ corresponds to a Paretian equilibrium. That is to say at this point any variation ($d\pi_1$, $d\pi_2$) makes at least one player dissatisfied (his gain decreases). In other words, the sum of the two profits is maximal. When they "cooperate" to fix the π_i the operators should choose $\pi_1 = c_1$ and $\pi_2 = c_2$. Then, when the regulator decides to decrease and cancel the access charges, the two profits decrease. Also, the framework of this paper appears: there is a two stage game. During the first stage, the operators cooperate to choose the access charges π_i. During the second stage, there is Nash equilibrium since the regulator prevents collusion (when the prices p_i are concerned). The "capping" (the regulator decides to decrease the access charges) prevents the operators choosing the level of access charges allowing higher profits.
The symmetrical case is very clear. The access charges trigger neither gain neither loss for the operators. But they have an effect on the prices, and the operators can obtain higher profits. When there are access charges the operators can choose them in such a way that the price is the monopoly price the cost being 2 c. They choose $\pi = c$. They maximize their profit, since the cost is 2 c. When the access charges are cancelled, the price is the monopoly price when the cost is c. It is lower. The profits have decreased. The consumers' surplus increases in each country. The total surplus in each country increases, since in the symmetrical case the flow of money because of access charges is equal to 0.

4. Case 2: in each country two operators sell traffic towards the other country.

In each country two operators (E_{11} and E_{12} in the country 1 and E_{21} and E_{22} in the country 2) sell traffic towards the other country. To simplify one supposes some symmetry: the two costs are equal in each country (c_1 and c_2). It is a Cournot competition. Each operator chooses the quantity of traffic it sells [5] [6].
The profit of E_{11} is written:

$$\prod_{11} = q_1 (p (q_1+q_2) - \pi_2 - c_1) + q_1/q_1+q_2 (\pi_1 - c_1) Q_2 \qquad (3).$$

Q_2 is given. It is the quantity of traffic sold in the country 2.
Nash equilibrium is written:

$$\partial \prod_{11} / \partial q_1 = 0,\ p (q_1+q_2) - \pi_2 - c_1 + q_1 p' (q_1+q_2) + q_2 / (q_1+q_2)^2 (\pi_1 - c_1) Q_2 = 0 \qquad (4).$$

One supposes $\partial^2 \prod_{11} / \partial q_1^2 < 0$ and $\partial^2 \prod_{12} / \partial q_2^2 < 0$.
Because of symmetry the quantity q_0 corresponding to Nash equilibrium is given by:

$$p (2q_0) - \pi_2 - c_1 + q_0 p' (2q_0) + 1/4q_0 (\pi_1 - c_1) Q_2 = 0 \qquad (5).$$

The formula (5) gives Q_0 ($Q_0 = 2q_0$) in function of Q_2 : Q_0 and Q_2 are the quantities sold in the countries 1 and 2. If Q_0 and Q_2 are strategic complements or substitutes depends on the sign of $\pi_1 - c_1$ and $\pi_2 - c_2$. Here, to simplify one supposes $c_1 = c_2$ and that the demands are the same (p (q)). There are two hypotheses which are possible:
Complements. The slope of the reaction function R_1 is positive and one supposes it is more than 1, to have a stable equilibrium (so the firms can find the equilibrium by groping). The equilibrium point is on the first bisector, at the intersection of the first bisector and R_1.
Substitutes. The slope of R_1 is negative. The equilibrium point is at the intersection of the first bisector and R_1.
At the equilibrium the flow of money for E_{11}thanks to access charges, is ½ $[-Q_0\pi_2 + Q_2\pi_1]$. So the regulator lets the profits untouched if he decides $d\pi_1 < 0$ and $d\pi_2 < 0$ such that: $d\pi_1 / d\pi_2 = Q_0 / Q_2$. The variation of the quantity in (5) is $- d\pi_2 > 0$.
It is easy to demonstrate that the derivative of the quantity in (5) in q_0 is negative (one uses $\partial^2 \prod_{11} / \partial q_1^2 < 0$). Therefore the reaction function is moved towards the right (Q_0 increases).
In the two hypotheses (complements and substitutes) the equilibrium point moves towards increasing quantities ($Q_0 = Q_2$ increases). Therefore the regulator can decrease the access charges in such a way that the profits are untouched (direct effect). Then the total quantity sold in each country increases (strategic effect). The consumers' surplus increases in each country. The total surplus increases in each country (given the symmetry).
When the access charges exist, the operators should cooperate to choose $\pi = c$. It maximizes the joint profit. The price is the monopoly price, the cost being 2c. And the cost of each operator is 2c. Each operator gains the half of the monopoly profit. When the access charges have been cancelled, the price is the monopoly price, the cost being 3c / 2. It is lower. The profits decrease. Notice that during this move (from $\pi = c$ to $\pi = 0$) the quantities Q_0 and Q_2 are substitutes.

5. Case 3: a large operator (tier 1) collects the traffic of local operators (tier 2).

A large operator E_1 (tier 1) collects the traffic of local operators (tier 2) and carries it towards the operator E_2 in the other country [7]. It chooses the price p_1, therefore the quantity of outward traffic is $D_1 (p_1)$. And it carries the inward traffic $D_2 (p_2)$ for π_1. Its cost is c_1. Indeed, the price p_1 is paid by the customers to the operators of the tier 2, and then the proceeds are passed to E_1, the payment for the operators of the tier 2 being kept. The "natural" payment is to pay the two kinds of traffic carried by the operators of the tier 2, the inward one and the outward one. The alternative would be to pay only the outward traffic, but it is obvious that the

operators of the tier 2 would make losses (the aggregate curve of the cost c (q) for the local operators is supposed increasing, and there are losses in the symmetrical case, the inward and outward traffics being the same). Therefore E_1 pays the local operators $[D_1 (p_1) + D_2 (p_2)]\ c\ (D_1 (p_1) + D_2 (p_2))$. The local operators are incited to produce the quantity of traffic $D_1 (p_1) + D_2 (p_2)$ to maximize their profit, $D_1 (p_1)$ corresponding to outward traffic and $D_2 (p_2)$ corresponding to inward traffic. Notice that when the regulator decreases and cancels the access charges, the prices p_1 and p_2 decrease and the profits of the local operators increase. They are in favor of this decision. They do not participate in the negotiation (since only the operators E_1 and E_2 pay for the access charges) but they are actors, and their point of view matters.
One can write the profit $\prod_1$:

$$\prod_1 = D_1 (p_1) (p_1 - c_1 - \pi_2) - [D_1 (p_1) + D_2 (p_2)]\ c\ (D_1 (p_1) + D_2 (p_2)) + (\pi_1 - c_1) D_2 (p_2) \quad (6).$$

The Nash equilibrium is written by deriving in p_1. One supposes $\partial^2 \prod_1 / \partial p_1^2 < 0$.From (6) one deduces that a decrease of the access charges such that $d\pi_1 / d\pi_2 = D_1 / D_2$ lets untouched the profits (direct effect). As $\partial \prod_1 / \partial p_1$ decreases when π_2 decreases, the price p_1 decreases (strategic effect). To simplify one can suppose the symmetrical case: the demands, the costs, the aggregate curve of the costs for local operators and the access charges are the same. The equation giving the Nash equilibrium is:

$$D' (p_0) (p_0 - c - \pi) + D (p_0) - D' (p_0) \quad c\ (2 D (p_0)) - 2 D (p_0)\ c' (2 D (p_0))\ D' (p_0) = 0 \quad (7).$$

The derivative of the expression in (7) is negative, if one makes the hypothesis of a curve of aggregate cost convex. Therefore the effect of $d\pi < 0$ is that p_0 decreases.
In each country the consumers' surplus increases. One calculates the variation of the total surplus, neglecting the flows of money because of the access charges. When q calls are sold in a country, the cost is: $2qc + \int_{0 \to 2q} c (q)\, d q = \int_{0 \to 2q} [c + c (q) \quad d q] = 2 \int_{0 \to q} [c + c (2q')]\, d q'$. It is as if the marginal cost was $2 (c + c (2q))$. Therefore the total surplus in each country increases. In the total surplus there is the profit of the operators of the tier 2, which increases. Also, one demonstrates that if the operators of the tier 1 choose some value $\pi > 0$, they maximize their profit. To sum up: when the access charges are lowered and cancelled, in each country the consumers' surplus increases, the total surplus increases, the profits of the operators of the tier 2 increase and the profits of the operators of the tier 1 decrease (if they have chosen $\pi > 0$ to maximize their profit).

6. Case 4: two operators are connected and competitors.

In some country, there are two operators which are connected (the subscribers of one of these operators can call the subscribers of the other). One supposes Cournot competition. The outward traffic for each operator is $q_1 q_2 / q_1 + q_2 N$ (N being the total number of subscribers in the country, where all the households are subscribers). The inward traffic is $q_1^2 / q_1 + q_2$ for E_1 and $q_2^2 / q_1 + q_2$ for E_2.
The profits are written:

$$\prod_1 = q_1 [p (q_1 + q_2) - 2 c_1] + q_1 q_2 / q_1 + q_2 [\pi_1 - \pi_2] \quad (8).$$

It is the same for $\prod_2$, reversing the indices.
The Nash equilibrium is written/

$$\partial \prod_1 / \partial q_1 = 0,\ p (q_1 + q_2) - 2 c_1 + q_1 \quad p' (q_1 + q_2) + q_2^2 / (q_1 + q_2)^2 (\pi_1 - \pi_2) = 0 \quad (9).$$

First, in the symmetrical case ($c_1 = c_2$) the access charges are equal and have no role. The Nash equilibrium is always the same, no matter the value of π. It is the Cournot equilibrium the costs being 2c.
Second, when c_1 and c_2 are different, the cancellation of the access charges triggers changes of q_1 and q_2 in opposite directions.
If $\pi_i < \pi_j$, q_i is a substitute and one can suppose that q_j also. In this case, when the access charges are cancelled, q_i increases and q_j decreases. It is not very interesting for the regulator, even if $q_1 + q_2$ can increase. Also, one demonstrates that the Paretian equilibrium exists, but the operators cannot reach it thanks to the access charges. Possibly, they can choose the level of the access charges such that each makes more gain.
In any case, if the costs c_1 and c_2 are equal or have nearby values, there is no effect of access charges, or they have a little effect.
The access charges have a role when the "club effect" is taken into account. Often an operator offers a "Friends and Family" like tariff to its subscribers: it is to allow calls towards several subscribers of the same operator for some advantageous price. If one supposes two operators E_1 and E_2, one (E_1) offering this kind of tariff and the other (E_2) not, access charges will have a role.
To model the "club effect" one imagines two packages of services: (1) the standard package is the possibility of calling any subscriber in the country, the quantity of traffic being limited. There is a fee to pay. (2) the sophisticated package is the standard package plus the possibility of calls lasting a long time, to several subscribers of the same operator ("Friends and Family" tariff). There is a fee to pay.
On a graph O u_1 u_2, the consumers are shown by points (u_1, u_2), u_1 being the utility of the sophisticated package and u_2 being the utility of the standard package. The points are on the right of the first bisector. One obtains the demand $D_i (p_1, p_2)$ integrating the density of utility $d (u_1, u_2)\, d u_1\, d u_2$ on the domain $D_i (u_i - p_i > u_j - p_j,\ u_i - p_i > 0)$. It is shown on the figure 2.

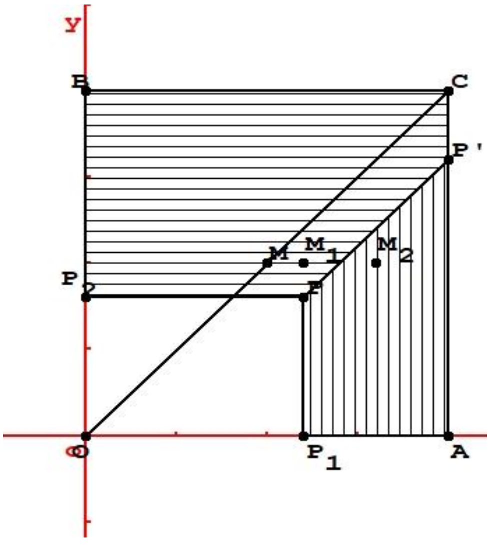

Figure 2. The customers of E_1 and E_2 are shown. In M, there is a consumer who is indifferent to the sophisticated package. In M_1 and M_2 there are consumers who appreciate the sophisticated package, but the consumer in M_2 appreciates it more than the consumer in M_1. When the prices are p_1 (O P_1) and p_2 (O P_2) the domains D_1 and D_2 are shown. D_1 is hatched vertically. D_2 is hatched horizontally.

One writes the profits:

$$\prod_1 = p_1 D_1 - Q_1 (p_1, p_2) c_1 + D_1 D_2 / D_1 + D_2 [\pi_1 - k (p_1, p_2) \pi_2]$$
$$\prod_2 = p_2 D_2 - Q_2 (p_1, p_2) c_2 + D_1 D_2 / D_1 + D_2 [- \pi_1 + k (p_1, p_2) \pi_2] \quad (10)$$

$Q_1 (p_1, p_2)$ and $Q_2 (p_1, p_2)$ are the traffic generated on the networks of E_1 and E_2 when the prices are p_1 and p_2. And $k (p_1, p_2)$ is explained by the "club effect". There is more outward traffic on the network of E_2 ($D_1 D_2 / D_1 + D_2$) than on the network of E_1 ($k (p_1, p_2)\ D_1 D_2 / D_1 + D_2$, with $0 < k (p_1, p_2) < 1$). In average, the

subscribers of E_2 make more outward calls than the subscribers of E_1. More often than the subscribers of E_2, the subscribers of E_1 make inward calls, calling friends and parents, and speaking a long time with them.
The equations giving the Nash equilibrium are:

$$\partial \prod_1 / \partial p_1 = 0$$

$$\partial / \partial p_1 [p_1D_1\text{-}Q_1c_1] + \partial / \partial p_1 [D_1D_2/D_1+D_2] [\pi_1 - k (p_1, p_2) \pi_2] - D_1D_2/D_1+D_2 \quad \partial k (p_1, p_2) / \partial p_1 \pi_2$$

$$\partial \prod_2 / \partial p_2 = 0$$

$$\partial / \partial p_2 [p_2D_2\text{-}Q_2c_2] + \partial / \partial p_2 [D_1D_2/D_1+D_2] [- \pi_1 + k (p_1, p_2) \pi_2] - D_1D_2/D_1+D_2 \quad \partial k (p_1, p_2) / \partial p_2 \pi_2 \quad (11)$$

One supposes a stable equilibrium and prices being complements.
The regulator can decrease the access charges letting untouched the profits if $d\pi_1 / d\pi_2 = k$ (direct effect). Then the two prices p_1 and p_2 decrease (strategic effect). One takes into account: $\partial k (p_1, p_2) / \partial p_1 < 0$ and $\partial k (p_1, p_2) / \partial p_2 > 0$ (12).
When p_1 increases (p_2 increases) there are more (less) customers appreciating the "Friends and family" like tariff and there is more (less) inward traffic. This deserves more explanations. When one looks at the figure 2 one sees that if the price p_2 is fixed, the difference $u_1 - u_2$ is the opportunity cost for a customer of the operator E_1: he accepts to pay for less than $u_2 - u_1$ to benefit from the particular tariff, not more. The quantity of communication he consumes $q (u_1, u_2)$ is increasing in u_1 and decreasing in u_2. When the opportunity cost is more the price p_2 being fixed, it is clear that the customer wants to pay more money the price being the same (if the tariff is too expensive). Therefore he consumes more communication. And if the opportunity cost ($u_2 - u_1$) is the same the price p_2 being higher, the customer corresponding to higher p_2 consumes less. That is why $q (u_1, u_2)$ is increasing in u_1 and decreasing in u_2 and decreasing when $u_2 - u_1$ is constant and u_1 increases. Now to have (12) one supposes that the average $q_m (p_1, p_2)$ on the domain D_1 is increasing in p_1 and decreasing in p_2. Indeed, it depends on the density $d (u_1, u_2)$. One demonstrates that if the density is constant, $q_m (p_1, p_2)$ is increasing in p_1 and decreasing in p_2. Also, if the density has the same properties than $q (u_1, u_2)$ (that is to say continuous, increasing in p_1, decreasing in p_2 and decreasing when $u_1 - u_2$ is constant and $u_1$increases) the result holds.
After several steps π_1 and π_2 are equal to 0, or π_i is equal to 0 and π_j very small. Either the access charges are cancelled. The consumers' surplus has increased. Either the regulator can cancel π_j, which is very small. This does not change the result (the consumers' surplus increases).

7. Conclusion.

One has modeled four simple, typical cases to show the effects of the decrease and cancellation of the access charges. One has insisted on the tactical feasibility of this measure. When the regulator decides some decrease of the access charges, there is no effect on the profits, given the present state of the traffic (direct effect). So the operators cannot protest. However there will be a new Nash equilibrium, the prices will decrease and the profits will be lowered (strategic effect). But if the operators protest, they admit that the high level of the access charges is useful to have higher profits. And it is thanks to high retail prices, which is detrimental to consumers. Finally, it is difficult to protest in these conditions: in principle, higher prices paid by the consumers have to be justified by some performance (achieved by the operators). Of course, the regulator has power. But also, he has to negotiate with the operators permanently. That is why the tactical feasibility of his decisions matters (in other words, his decisions have to be acceptable for the operators).
In any way, game theory allows "experiences of thought" [8]. In this experience of thought, one observes the regulator decreasing and cancelling the access charges. It is tactically feasible. The effect is a decrease of the retail prices, which is beneficial to consumers. The consumers' surplus increases. The total surplus increases.
Concerning future work on this topic, it could concern … history. Indeed, anywhere the access charges are disappearing or have disappeared. The model is peering.
The professional milieu of telecommunications is livened up by controversies lasting decades. The controversy about access charges is one of them. But a new controversy appears, about a similar topic: that about Net neutrality. A similar stake is concerned: the revenues of the operators. But they should not come from access charges, but from the sale of differentiated services, paid for by those who provide the contents which are carried on Internet. So the following work should concern the topic of Net neutrality.
The differences between the two controversies can be described having recourse to the sociology of networks [9]. The social is explained in terms of actors – networks, made up of actors and actants (objects, like technical equipments). The milieu of telecommunications is an actor – network (made up of operators, the regulator etc. and objects like networks, cables, satellites…). There are controversies in it. For the analyst, it is interesting to understand the evolution of controversies to perceive the "creativity", which stems from some surprising connection (between actors-networks).
The differences between the two controversies are shown in the Table 1.

Table1. The differences between the two controversies (about access charges and about Net neutrality) are shown.

	Controversy about access charges	Controversy about Net neutrality
Time	Ending	Not yet stabilized
Translation into politics Regulation	Asymmetrical regulation favorable to consumers	Regulation favorable to operators
Stakes	Consumers' surplus	Revenues for operators
Ontology	Networks are poised to carry large amounts of data	Networks are poised to provide differentiated services QoS (Quality of service)

References.

[1] encyclopedia.thefreedictionary.com Article: "termination rates" (2017).
[2] encyclopedia.thefreedictionary.com Article: "peering" (2017).
[3] Williamson O Les institutions de l'économie (« The economic institutions of the capitalism »). InterEditions (1994).
[4] Baranes E and Jeanneret H M Article Ouverture des réseaux de télécommunications : problèmes et enjeux (« Open provision of telecommunications networks : problems and stakes ») in La Revue Economique, vol. 47, n° 6. Presses de Sciences Po (1996).
[5] Tirole J Théorie de l'organisation industrielle (« Theory of industrial organization »). Economica (1995).
[6] The New Palgrave Dictionary of Economics Article: Cournot competition. Authors: Baye R and Kovenock D Macmillan Publishers (2008).
[7] encyclopedia.thefreedictionary.com Article "tier 1 network" (2017).
[8] Lefebvre O Game theory and the stakes in the telecommunications industry. Lambert Academic Publishing (2014).
[9] Latour B Changer de société: refaire de la sociologie (Re-assembling the social: an introduction to the actor-network theory) La Découverte (2007).