Telecommunication Network Competition: An Equilibrium Analysis ♣

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Abstract

The paper analyzes calling party pays access pricing policies in a General Equilibrium two ways access charge model with consumers that choose between different telecommunication providers, and benefit from making calls to other consumers and from the calls that they receive. We obtain that agents' network decision may leads to an inefficient industry structure where from a social point of view the network competitively chosen by the agents is an inferior one. Under ad-hoc parameter values we obtain that if each telecommunication company faces a fixed cost, becomes of higher efficient to finance this cost through a fixed charge on the telephone line, an access charge, and setting telecommunication companies interconnection charges equal to each company interconnection marginal cost, where policies that finance fixed or common costs by increasing interconnection charges lead to less efficient allocations. And also we obtain that if the companies have different interconnection marginal cost, interconnection charge differences should be transferred to the final consumer prices, and interconnection charges should be adjusted to the companies' interconnection marginal costs.

1.- Introduction

In network industries such as telecommunication, gas, electricity, water and sewage services is possible to identify areas where competition is feasible and desirable, while in other areas competition is more difficult do to the natural monopoly characteristics of the industry. In the last two decades in many countries utilities regulation change direction to recognize those areas where competition is feasible, to incentive the entry of new agents, while it keeps regulated tariffs in those areas where competition have been less efficient. The telecommunication industry have been one of the most dynamic explained by its high growth rates and strong technological innovation, facts that in the last years have shake the structure of the industry.

Telephone networks are characterized by strong scale and scope economies,[1] economies that added to the network externalities that affect the users of the telecommunication service,[2] imply that the established telephone services provider counts with an advantage over new entrants. To neutralize this advantage, in many countries regulatory policy have made mandatory the networks interconnection, what allows the users to contact any other user or services provider independently of the company with which they sign up for the telephone service. Notwithstanding, mandatory networks

[1] See Cribbet (2000).

[2] See Squire (1973).

interconnection will be senseless without appropriate interconnection charges and final services prices.

In this paper we analyze interconnection pricing policies in a calling party pays regime (CPP), where government subsidies are not available, using a General Equilibrium two way interconnection network model with consumers that choose between different telecommunication providers, and where the consumers benefit from making calls to other consumers and from the calls that they receive. The framework that we consider is more flexible than standard Hotelling models of consumer differentiation as developed by Armstrong (1998), Laffont, Rey, and Tirole (1998a and b), and inelastic demand models where consumers demand one unit of a final good.[3] In the model that we develop there is a one to one distinct personal telephone contact between each pair of telephone user, relation that may not to be the same within other pairs of telephone users. Once a consumer becomes a subscriber of a telecommunication company, the company monopolizes the access to this user, and this is an essential input for other telecommunication companies to provide a complete final service to all the subscribers. Depending on the substitution degree of the services offered by the telecommunication companies, capture by a consumers' loyalty preference parameter, the telecommunication companies may or not compete for the same universe of subscribers.

The structure that we analyze resembles today's telecommunication industry and policy challenges confronted by regulatory authorities in many countries where the opening of the telecommunication industry to competition have posted some important questions. Here we analyze three questions of general concern that largely have been debated in Chilean telecommunication industry. First, with prices set according to marginal costs and in a free market regime, does the telecommunication company chosen by decentralized consumers leads to an efficient development of the industry?[4] Our second

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[3] The model most frequently used in the literature, developed by Armstrong (1998), Laffont, Rey and Tirole (1998a-b), is build upon the Hotelling model, with an infinite number of consumers whose preferences are uniformly distributed in the unit interval. In general and in the consumers preference parameter space, the model is presented as one where company one offers a variety that correspond to point cero and company two offers a variety that correspond to point one, where consumers incur a cost from choosing a particular telecommunication provider given by theirs' and the telecommunication company location in the preference parameter space. Each telephone user makes a number of calls that depend on prices but are independent on who they call, and each consumer calls are basically uniformly distributed within all other users.

[4] This issue is not analyzed in the seminal works of Armstrong (1998) and Laffont, Rey and Tirole (1998), where their emphasis is on matters such as if the setting of the access charges could be delegated to the operators or if it could be preferable to maintain a regulated approach. In essence they consider a case where telecommunication companies freely chooses final consumers prices and in their model the inefficiencies rest on the companies' strategic or monopolistic pricing behavior. Basically they find that freely negotiated access charges can have adverse effects on competition, for example in the mature phase of the industry allowing collusion and a price mark-up above cost, and also as an entry barrier for new comers. On a different edge, in the General Equilibrium framework that we use the emphasis is on

question looks at the optimality of recovering fixed or common costs using a fixed component in a two part tariff pricing policy regime instead of scaling the access charges above marginal costs to account for the fixed or common costs, and evaluate the efficiency of pricing policies where the financing of these costs is by setting a fixed entry charge for the telephone line; or setting telecommunication companies interconnection charges equal to the interconnection marginal cost of the company with the lowest interconnection marginal cost; or setting the telecommunication companies interconnection charges equal to the interconnection marginal cost of the company with the largest interconnection marginal cost?[5] And third, if the companies have different interconnection marginal cost that are reflected in the companies interconnection charges, the interconnection charge differences should be transferred to the final consumer prices? [6]

To answer these questions we analyze the equilibrium properties of the General Equilibrium CPP two way access charge model and also perform some numerical experiments on it. With respect to our first question, we obtain that there is no guarantee that the network chosen by decentralized agents leads to an efficient development of the industry. Basically, the lack of coordination between the agents can lead to an inefficient development of the industry.[7] Further, within our CPP regime higher efficiency is not necessarily guarantee by having the consumers choosing the network with the lowest termination cost,[8] and it depends on the alignment of social and private incentives in terms of the final prices faced by the consumers, what relies on the cost of

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modeling consumers' choices, in terms of their calls patterns and network choices, where a large number of potential telephone companies can freely enter the market.

[5] Our findings complement Armstrong (1998), Laffont, Rey and Tirole (1998) work's, where they analyze a symmetric model that under linear tariffs the Ramsey solution is to set the final consumers price equal to the variable cost plus the final subscriber fixed connection cost, and the access charge should be set equal to the marginal cost of access; and under non linear tariffs the usage prices is equal to the marginal cost and the fixed fee should be set equal to the final subscriber fixed connection cost, and the access charge should be set equal to the marginal cost of access. Also, Laffont, Rey and Tirole (1998) obtain that free price discrimination between on-net and off-net calls improves welfare respect to case where the telecommunication companies charge a symmetric free price for on-net and off-net calls.

[6] Carter and Wright (2003) with asymmetric networks, look at a different problem. They analyze the strategic incentives of the smaller and the larger network to ask for symmetric or asymmetric access charges; and Peitz (2004), in a liberalized telecommunication market, show that asymmetric access price regulation with a cost based access price regulation for the incumbent and an access markup for the entrant is more successful than cost-based access markup for the entrant and the incumbent what is done to provide strength for the entrant until it can compete on an equal basis with the incumbent..

[7] For the economics of networks competition see Liebowitz and Margolis (1994 and 1998), Kats and Shapiro (1985 and 1994), and Besen and Farrel (1994).

[8] For example, Armstrong (2002) in a non linear pricing regime obtains for the first best outcome that prices should be set to attract more subscribers onto the network with the lower termination cost.

initiating and finishing a call in each and within networks. With respect to the second question we obtain that is more efficient the financing of telecommunication companies fixed cost with a fixed charge per line, setting the prices for telephone calls at their marginal cost, instead of collecting part of the required revenues by increasing the companies termination charge above marginal cost. Finally, on the third question we obtain that is more efficient to have discriminatory pricing for on-net and off-net calls based on cost differences, where a reciprocal or symmetric interconnection charge policy where companies interconnection charges are equalized to the termination cost of the company with the largest or smallest termination cost leads to less efficient resource allocations.

In section two we describe the general equilibrium two way interconnection network model with heterogeneous agents. In section three we analyze the three questions posted. And finally in section five we give the main conclusions of the paper.

2.- The model

There are M price taker potential companies or interconnected telephone networks, j = 1,…,M, where each monopolizes the access to its subscribers. If the network infrastructure of two or more companies is symmetric or overlapped (according to a consumers' loyalty preference parameter) the companies will compete for the same universe of subscribers, supplying services that in the extreme can be perfect substitutes. To happen a situation like this is required for the networks to share the same effective coverage area as well as that the supplied service is identical (this mean that the users must perceive the service offered by each company as identical or as close substitutes). If the network infrastructure of two or more companies is asymmetric or not overlapped, the companies do not compete for the same universe of subscribers, what can happen in a case where the companies provide a different service (not a perfect substitute of each other) or provide telecommunication services to users located in different geographic areas (capture in our model by the consumers loyalty preference parameter that have an equivalent role to the Armstrong (1998) and Laffont, Rey and Tirole (1998) travel cost parameter used in the Hotelling model). From the consumers perspective, if the companies' network infrastructure is symmetric or asymmetric depends on network infrastructure location, technology, pricing policies, as well as preference parameters values.

2.1.- Consumers

There are N potential consumers, i = 1,…,N, who are price takers and take as given other agents decisions. If a consumer contracts the telecommunication service with a telecommunication company, she/he obtains utility from the calls made to other subscribers, from the calls received from other subscribers,[9] and from the consumption

[9] The presence of the call externality is an important aspect of the telecommunication industry, where some agents have a telephone mostly to receive calls and not to make calls. Jeon, Laffont and Tirole (2004), Berger (2002) and Peitz (2004) extend standard Hotelling model to account for the externality of

of a basic good that represents all the other goods available in the economy, whose price is normalized to one. Since there are M potential companies, each consumer can choose among M+1 potential locations (not being a member of a company considered).

Since there are N potential consumers and M+1 potential locations for each consumer within the different companies (set j = 0 for not being a member of any network), we have that there are $(M+1)^N$ possible arrays of the N consumers in the M different companies (not being a member of a telecommunication company considered). However, M×N of the last arrays are trivial because are cases where only one agent is subscriber of a telephone company and the others are not. Thus, the number of significant arrays to be considered are $T = (M+1)^N - M\times N$. Lets' index by t each of the significant arrays where each of the consumers belong to one of the networks (not being a member of a telecommunication company considered), then t = 1,…, T.

If array t takes place, consumer i utility is given by:

$$U^i(t) = v^i(t) \sum_{s=1, s\neq i}^{N} \beta^{is} \ln\left(1 + \phi_s^i C_s^i(t) + \left(1-\phi_s^i\right)\bar{C}_i^s(t)\right) + g^i Y^i(t)$$

where $v^i(t) \geq 0$ is a loyalty preference network parameter that weights consumer utility from being in network j, j = 0,…,M, if network j is the network where agent i is appointed in array t. Notice that $v^i(t) = 0$ when j = 0 and agent i is not appointed to any telecommunication network in array t. $C_s^i(t)$ are calls made by consumer i, who is a subscriber of network j in array t, to consumer s, who is a subscriber of network r in array t, and $\bar{C}_i^s(t)$ are calls made by consumer s, who is a subscriber of network r in array t, to consumer i, who is a subscriber of network j in array t. ϕ_s^i is a preference parameter, $0 \leq \phi_s^i \leq 1$, that accounts for the relative value that consumer i gives to the calls that she/he makes to consumer s against the calls that she/he receives from consumer s, it weights $C_s^i(t)$ against $\bar{C}_i^s(t)$ or the externality for agent i to receive a call from agent s. $\beta^{is} \geq 0$ is consumer' i preference parameter that value the utility from the calls made and received from consumer s, s = 1,…M, $s \neq i$, it picks up the fact that each consumer benefits from contacts with a reduced number of other consumers and not necessarily with all the other agents that has a telephone.[10] g^i is the marginal utility of

receiving a call. They found that efficiency points to set access charges below marginal cost or to adopt a termination discount.

[10] For example in Armstrong (1998), and Laffont, Rey and Tirole (1998), each consumers calls distribute uniformly within all the other consumers with a telephone.

income and $Y^i(t)$ is agent *i* consumption of other goods different to telecommunication services in array *t*.[11]

Let $I^i(t) \in [0,1]$, *j*=0,1,…,*M*, be a function that gives the chances by which agent *i* chooses array *t*, $\sum_{t=1}^{T} I^i(t) = 1$. Also for agent *i* let $\bar{I}^{is}(t) \in [0,1]$, $\sum_{t=1}^{T} \bar{I}^{is}(t) = 1$,be a function that gives the chances expected by agent *i* that agent *s* chooses array *t*. As a result, accounting for consumers' network choices, consumer *i* ex-ante preferences are represented by the utility function:

$$U^i = \sum_{t=1}^{T} \left\{ I^i(t) \prod_{s=1, s\neq i}^{N} \bar{I}^{is}(t) \right\} \times \left\{ U^i(t) \right\}$$

Thus, for preferences defined over all these goods, consumer *i* choice variables are $\left\{ \left\{ C_s^i(t) \right\}_{s=1, s\neq i}^{N}, Y^i(t), I^i(t) \right\}_{t=1}^{T}$, where the consumer chooses (N+1)×T variables.

Let $P^{jr}(t)$ be the price for a consumer to initiate a call in network of company *j* and to end a call in the network of company *r* in array *t*, and let $T^j(t)$ be the fixed charge paid by a consumer from having a telephone of company *j* in array *t*. Thus, given prices, consumer *i* utility maximization problem is:

$$\underset{\left\{ \left\{ C_s^i(t) \right\}_{s=1, s\neq i}^{N}, Y^i(t), I^i(t) \right\}_{t=1}^{T}}{Max} U^i$$

$$s.t.$$

$$\sum_{s=1, s\neq i}^{N} P^{jr}(t) C_s^i(t) + Y^{ij}(t) + T^j(t) \leq m^i + \sum_{j=1}^{M} \rho^{ij} \pi^j(t),\ t = 1, ..., T$$

$$I^i(t) \in [0,1], t = 1, ..., T;\ \sum_{t=1}^{T} I^i(t) = 1$$

$$C_s^i(t) \geq 0, s = 1, ..., N, s \neq i,\ t = 1, ..., T$$

$$Y^i(t) \geq 0,\ t = 1, ..., T$$

where m^i is the consumer's *i* endowment of the basic good, ρ^{ij} is consumer's *i* ownership share of firm *j* and $\pi^j(t)$ are firm *j* profits under array *t*, $0 \leq \rho^{ij} \leq 1$ and $\sum_{i=1}^{M} \rho^{ij} = 1$.

Given the consumer network choice $I^i(t)$, we have a well defined twice differentiable concave optimization problem over a compact and convex set, problem that has a

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[11] For computational convenience we use a logarithmic utility function where depending on ϕ_s^i, C_s^i and $\bar{C}_i^s$ can perfectly substitute for each other. Also, the assumption that the weighting parameter that multiply C_s^i and $\bar{C}_i^s$ add up to one, ϕ_s^i and (1- ϕ_s^i), can be relaxed.

unique solution.[12] Thus, the solution of the consumer optimization problem is given by the choice, if any, of being a client of one of the telecommunication companies where she/he maximizes utility. From first order conditions we obtain that

$$\partial C_s^i(t): \frac{v^i(t)\beta^{is}\phi_s^i}{1+\phi_s^i C_s^i(t)+\left(1-\phi_s^i\right)\bar{C}_i^s(t)} - \lambda^i(t)P^{jr}(t) \quad \leq \quad 0; \text{ with } \quad "=" \quad \text{if} \quad C_j^i(j,r)>0$$

where $\lambda^i(t)$ is the Lagrange multiplier under array t, and is equal to the marginal utility of income g^i. Thus, in an interior solution when $C_s^i(t) > 0$ is obtained that:

$$C_s^i(t) = \frac{v^i(t)\beta^{is}}{g^i P^{jr}(t)} - \frac{1+\left(1-\phi_s^i\right)\bar{C}_i^s(t)}{\phi_s^i}$$

From this demand at the consumer level we obtain the following results:

a) $\frac{\partial C_s^i(t)}{\partial P^{jr}(t)} < 0$ b) $\frac{\partial C_s^i(t)}{\partial \bar{C}_i^s(t)} < 0$

c) $\frac{\partial C_s^i(t)}{\partial v^i(t)} > 0$ d) $\frac{\partial C_s^i(t)}{\partial g^i} < 0$

e) $\frac{\partial C_s^i(t)}{\partial \phi_s^i} > 0$ f) $\frac{\partial C_s^i(t)}{\partial \beta^{is}} > 0$

Thus, if the price that pays consumer *i* who is in network *j* to call consumer *s* who is in network *r* increases, then the number of calls that consumer *i* makes to consumer *s* will diminish. If the number of calls that consumer *s* makes to consumer *i* increases, then diminishes the number of calls that consumer *i* makes to consumer *s*. If the loyalty preference network parameter $v^i(t)$ that weights consumer *i* utility from being in network *j* under array *t* increases, calls from consumer *i* who is in network *j* to consumer *s* who is in network *r* increases. If the marginal utility of income increases, then calls from consumer *i* to consumer *s* decreases. If ϕ_s^i increases, the preference parameter that accounts for the relative significance of $C_s^i(t)$ and $\bar{C}_i^s(t)$, then calls from agent *i* to agent *s* increases. And finally, if the preference parameter β^{is} that value consumer *i* utility from having a contact with consumer *s* increases, calls from consumer *i* who is in network *j* to consumer *s* who is in network *r* increases.

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[12] It should be noticed that in some arrays *t* may happen that consumer *i* disposable income $m^i + \sum_{j=1}^{M} \rho^{ij}\pi^j(t) - T^j(t) \leq 0$, then as a solution we take that the consumer makes no calls and only for that cases we set $Y^{ij}(t) = m^i + \sum_{j=1}^{M} \rho^{ij}\pi^j(t) - T^j(t) \leq 0$.

Given consumers' call patterns we can obtain the demand for traffic for on-net and off-net calls for each telecommunication network by summing up the calls of the different consumers. Thus, the demand for traffic from network *j* to network *r* in array *t* is:

$$\sum_{\substack{i=1 \\ i\neq s \\ i \text{ is in } j}}^{N} \sum_{\substack{s=1 \\ s\neq i \\ s \text{ is in } r}}^{N} C_s^i(t) = \sum_{\substack{i=1 \\ i\neq s \\ i \text{ is in } j}}^{N} \sum_{\substack{s=1 \\ s\neq i \\ s \text{ is in } r}}^{N} \left[\frac{v^i(t)\beta^{is}}{g^i P^{jr}(t)} - \frac{1+(1-\phi_s^i)\bar{C}_i^s(t)}{\phi_s^i} \right], \; t=1,\ldots,T$$

and in equilibrium is equal to supply $Q^{jr}(t)$. Also, access demand or the number of subscribers of company *j* network in array *t* are $N^j(t)$, and in equilibrium is equal to access supply.

2.2.- Technology, Costs, and Profits

Let $p^{jo}(t)$ ($p^{je}(t)$) be the price charged by company *j* for initiating (ending) a call in his network under array *t*. Let c^{jo} (c^{je}) be the cost to initiate (end) a call in network *j*, let C^j be network *j* fixed cost, and let $Q^{jr}(t)$ be the traffic supply from network *j* to network *r* in array *t*, and $N^j(t)$ network *j* subscribers in array *t*. Then, in array *t* company *j* total costs are

$$TC^j(t) = \left(c^{jo} + c^{je}\right)Q^{jj}(t) + \sum_{\substack{r=1 \\ r\neq j}}^{M} (c^{jo} + p^{re}(t))Q^{jr}(t) + \sum_{\substack{r=1 \\ r\neq j}}^{M} c^{je} Q^{rj}(t) + C^j,$$

and company *j* total revenues are

$$R^j(t) = P^{jj}(t)Q^{jj}(t) + \sum_{\substack{r=1 \\ r\neq j}}^{M} P^{jr}(t)Q^{jr}(t) + \sum_{\substack{r=1 \\ r\neq j}}^{M} p^{je}(t)Q^{rj}(t) + T^j(t)N^j(t).$$

Given prices, company *j* total profits and optimization problem in array *t* is:

$$\pi^j(t) = \underset{\left\{Q^{jj}(t), \left\{Q^{jr}(t), Q^{rj}(t)\right\}_{\substack{r=1 \\ r\neq j}}^{M}, N^j(t)\right\}}{Max} R^j(t) - TC^j(t)$$

Given array *t* we have a well defined linear optimization problem for which a solution exists.

2.3.- Equilibrium

We assume that individuals know all the prices and know when they call a subscriber of network *j* or of network *r*.[13] Also, network interconnection is mandatory within the

[13] In practice this assumption of complete knowledge can be implemented with the existence of a digit that identifies the network that is being called, or that during the call the calling party hear a different tone

different companies that serve the industry, and companies have a mandatory service obligation as long as they incur no losses, and the interconnection charges and final service prices are taken as given by the companies.

A General Equilibrium for this model is a consumption plan for each consumer, $\left\{ \left\{ C_s^i(t) \right\}_{s=1, s\neq i}^{N}, Y^i(t), I^i(t) \right\}_{t=1}^{T}$, i = 1,…,N, a production plan for each company, $\left\{ Q^{jj}(t), \left\{ Q^{jr}(t), Q^{rj}(t) \right\}_{\substack{r=1 \\ r\neq j}}^{M}, N^j(t) \right\}$, j = 1,…,M, t = 1,…, T, and a price vector, $\left\{ T^j(t), P^{jr}(t), p^{je}(t), p^{jo}(t) \right\}_{\substack{j=1,\dots,M \\ r=1,\dots,M}}$, t = 1,…,T, such that at the given prices, and given other agents consumption plan, each consumer consumption plan maximizes utility; at the given prices companies' production plan maximizes profits; and there is market equilibrium:

$$\sum_{\substack{i=1 \\ i\neq s \\ i \text{ is in } j}}^{N} \sum_{\substack{s=1 \\ s\neq i \\ s \text{ is in } r}}^{N} C_s^i(t) \leq Q^{jr}(t), \text{ j = 1,...,M, r = 1,...,M, } t = 1,...,T;$$

in array t the number of subscribers in company j equals supply $N^j(t)$, j=1,…,M, t = 1,…,T. Also in the definition we should note that implicitly we assume that equilibrium in the intermediate service or access service market exists.

The sequence of the events in the model is that in the first stage the consumers choose a network, that defines an array t, and then in the second stage they choose the number of calls that they place in the system. As is set the model an Equilibrium in the can be obtained by backward solving. In the second stage within array t, with Brower fixed point theorem, and when prices are properly work out, the existence of equilibrium can be established. However in the first stage and given the nature of the consumers' network choice, when consumers' network choices are endogenously determined, the existence of equilibrium can not be guaranteed for a setting where consumers use pure strategies, and it only can be guarantee when they randomly choose a network, $I^i(t) \in [0,1], t = 1,...,T;\ \sum_{t=1}^{T} I^i(t) = 1$. It should be view that given array t, the consumers behave competitively with respect to the number of calls that they place to each other in the network, but is in terms of the consumers' telecommunication network decision, if any, that we have a game whose solution is given as Nash equilibrium.

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in the auricular, or that the subscribers are or not able to decide if their telephone is or not able to communicate other companies networks as occurs in some countries regarding the possibility to block calls to certain telephone numbers.

When consumers' network choices are taken as given,[14] we look for a Competitive Equilibrium in the consumers' decision in terms of the traffic that they place in the network. For it Walras Law can be confirmed from consumers budget constrain. Given array *t* and for price taking agents, it can be established a continuous correspondence for prices $\left\{T^{j}(t), P^{jr}(t), p^{je}(t), p^{jo}(t)\right\}_{\substack{j=1,\dots,M \\ r=1,\dots,M}}$ in a compact and convex set, what proves the existence of a Walrasian Equilibrium.

In array *t* and after consumers' network choices are given, from a consumer point of view T^j can be seen as a lump-sum transfer to the telecommunication company, so given $\left\{P^{jr}(t), p^{jt}(t), p^{je}(t)\right\}_{\substack{j=1,\dots,M \\ r=1,\dots,M}}$ the consumers' decision is restricted to choose the number of calls she/he will place to any other consumer. With $\left\{P^{jr}(t), p^{jt}(t), p^{je}(t)\right\}_{\substack{j=1,\dots,M \\ r=1,\dots,M}}$ being set at their marginal cost and setting the lump sum transfer $T^{j}(t) = C^{j} / N^{j}(t)$, j = 1,…,M, we can compute the equilibrium for price taking agents given array *t*, *t* = 1,…,T. Also, notice that under array *t*, the efficiency of the equilibrium will depend on the existence of call externalities, where if ϕ_s^i=1, *i*, *s* = 1,…, N, the equilibrium is efficient and satisfy the 1rst Welfare Theorem (where the fixed charge T^j, *j* = 1,…,N, should be seen as a lump-sum transfer that allows the companies to recover their fixed cost).

Next, in the first stage the consumers decide on which network, if any, each of them will contract telecommunication services, what stands up for a game where consumers strategically choose between the different networks, game whose solution is a Nash Equilibrium. Thus, given second stages Competitive Equilibrium, within each array *t*, *t* = 1,…,T, to obtain an Equilibrium in the first stage, we can construct a continuous correspondence for consumers' network choices $\left\{I^{i}(t)\right\}_{t=1}^{T}$, *i* = 1,…,N, in a compact and convex set, where Kakutani fixed point theorem assures that there is a Nash equilibrium. As happen for any finite game, the existence of the equilibrium can only be guaranteed if the consumers randomly choose between the different networks as well it happen that the equilibrium may be not unique.

To address the questions announced in the introduction, in what follows we will numerically compute Nash equilibrium in a simplified case where there are four potential subscribers, that play pure strategies in terms of network choice, and free entry into the market leads at most to the entry of two companies.

3.- Experiments

The interconnection to network *j* is an essential input to complete a telephone call originated in network *r* or alternatively is an essential input so that the business owner

[14] Notice that there are T possible arrays of the N consumers in the M different companies and not being a member of a telecommunication company considered.

of network r can sell services to network j subscribers. With the increasing degrees of competition in world wide telecommunication industry, regulators face fundamental questions about competition, efficiency and price regulation of the telecommunication industry. With the two way general equilibrium interconnection network model we bring in answers to questions as: first, in a situation where companies can freely enter the industry, consumers network choice will lead to an optimal development of the industry?; second, if telecommunication companies confront a fixed or common cost, what price adjustment gives larger social welfare, to set a fixed entry charge for the telephone line, to set telecommunication companies interconnection charges equal to the interconnection marginal cost of the company with the lowest interconnection marginal cost, or to set the telecommunication companies interconnection charges equal to the interconnection marginal cost of the company with the largest interconnection marginal cost; and third, when the regulator calculates termination or interconnection charges into the different telecommunication networks, the interconnection charges should be symmetric or asymmetric for the different networks?, and if they are asymmetric, what are the effects that the differences in interconnection charges are or not transfer to the public or final user?

In what follows and to address these important questions we perform three numerical experiments using the CPP General Equilibrium two way interconnection network model just developed:

Experiment 1.- Optimal network selection
Experiment 2.- Tariff adjustment
Experiment 3.- Interconnection charge differences transferred to the public

For the experiments we assume $\rho^{ij} = \frac{1}{N}$, for all (i,j) pair in N×M, and that consumer i preference parameter that value the utility from the calls made and received from consumer s is $\beta^{is} = 1$, $i, s = 1,\ldots M$, $s \neq i$.

3.1.- Experiment 1.- Optimal network selection

The question is if decentralized telecommunication company selection by price taker consumers in a competitive environment where companies freely choose to enter or not the industry lead to an efficient development of the telecommunication industry?

Before we address the above question we already notice that within array t and as long as $\phi^{s}_{i} < 1$ for at least one $(s,i) \in$N×N, Competitive Equilibrium may not be efficient when the prices faced by the consumers differ from the social marginal benefit (*SMgB*) of calling each other. As a fact of the externality that a consumer has when she/he receives a call from other consumer, we have that the social marginal benefit of a call made from consumer i in network j to consumer s in network r in array t is:[15]

[15] This is beyond the tariff mediated network externality.

$$SMgB_s^i(t) = \frac{v^i(t)\phi_s^i}{g^i\left(1+\phi_s^i C_s^i(t)+\left(1-\phi_s^i\right)\bar{C}_i^s(t)\right)} + \frac{v^s(t)(1-\phi_i^s)}{g^s\left(1+\phi_i^s C_i^s(t)+\left(1-\phi_i^s\right)\bar{C}_s^i(t)\right)}$$

Given network choices, to have that consumer *i* makes a socially efficient number of calls to consumer *s* is needed that the social marginal benefit of a call from consumer *i* in network *j* to consumer *s* in network *r* is equal to the social marginal cost (*SMgC*) of that call, that in our model is $c^{jo} + c^{re}$. Thus, if consumer *i* pays a price to call consumer *s* that is equal to the *SMgC*, it will be that the number of calls that consumer *i* makes to consumer *s* is below what is socially optimum.

Beyond the last inefficiency due to the externality from receiving a call, and even if ϕ^i_s = 1 for all (*s,i*) pair,[16] the question is if consumers' network choice, with prices adjusted to costs, will lead to an efficient choice of the network in the industry?

From standard game theory we have that Nash Equilibrium may be not unique and by the lack of coordination it may not be Pareto Optimum. As it happens in a Prisoner's Dilemma, when the agents independently and without coordination choose, if any, a network may conduct in the first stage of the model to an inefficient resource allocation. Choosing ad-hoc parameter values set we illustrate an awful outcome in our model. For that, first we compute a model equilibrium where the consumers are free to choose if they contract telecommunication services with company 1 or company 2, and then compute a market equilibrium where we restrict the consumers only to become subscribers of company 1, and after that we compare the efficiency properties of both equilibrium.

Table 1.1 present the preference, income, and cost parameter values set that we particularly choose to perform the numerical experiment. From consumer preference and income parameter values we can appreciate that consumers are homogeneous, and also that in terms of their preference parameter values they perceive network 1 as a perfect substitute for network 2. Further, since $\phi^i_j = 1$, $i, j = 1,\ldots,N$, the consumers only receive utility from the calls that they made but receive no utility from the calls that they receive. In terms of the cost structure, while even there is no fixed or common cost in any network, $C^1 = C^2 = 0$, we have that network 2 is more efficient in the cost of originating a call than network 1, while network 1 is more efficient in the cost of terminating or finishing a call than network 2, $c^{1o} > c^{2o}$ and $c^{1e} < c^{2e}$.

Table 1.1
Experiment 1.- Technology and Preference Parameters

Technology		Preferences								
c^{1o}	0.003	Consumer	1		2		3		4	
c^{1e}	0.002	v^{i1}	1.000		1.000		1.000		1.000	
c^{2o}	0.002	v^{i2}	1.000		1.000		1.000		1.000	
c^{2e}	0.008	g^i	0.300		0.300		0.300		0.300	
C^1	0.000	m^i	10.000		10.000		10.000		10.000	
C^2	0.000		ϕ^1_2	1.000	ϕ^2_1	1.000	ϕ^3_1	1.000	ϕ^4_1	1.000
			ϕ^1_3	1.000	ϕ^2_3	1.000	ϕ^3_2	1.000	ϕ^4_2	1.000
			ϕ^1_4	1.000	ϕ^2_4	1.000	ϕ^3_4	1.000	ϕ^4_3	1.000

[16] Case where the externality from incoming calls does not apply.

Table 1.2 show the prices that we use for the experiment, where they have been set equal to marginal costs (MgC). From the table we see that is cheaper to call within network 1 than within network 2, and is cheaper to call from network 1 to network 2 than from network 2 to network 1, and that network 1 has lower termination or interconnection charges than network 2.

Table 1.2 Experiment 1.- Prices		
P^{11}	0,0050	= MgC
P^{12}	0,0011	= MgC
P^{22}	0,0100	= MgC
P^{21}	0,0040	= MgC
p^{1o}	0,0030	= MgC
p^{1e}	0,0020	= MgC
p^{2o}	0,0020	= MgC
p^{2e}	0,0080	= MgC
T^{1}	0,0000	
T^{2}	0,0000	

For Table 1.1 parameter values and Table 1.2 prices in Table 1.3 we show the computed model equilibrium on key variables when the consumers freely choose between being subscribers of company 1 or between being subscribers of company 2

Table 1.3 Experiment 1.- Outcome – Consumers freely choose being subscribers of company 1 or 2									
Consumer results								Company Profits	
I^{11}	0	I^{21}	0	I^{31}	0	I^{41}	0		
I^{12}	1	I^{22}	1	I^{32}	1	I^{42}	1	π^{1}	0.0000
C^{1}_{2}	332.3333	C^{2}_{1}	332.3333	C^{3}_{1}	332.3333	C^{4}_{1}	332.3333	π^{2}	0.0000
C^{1}_{3}	332.3333	C^{2}_{3}	332.3333	C^{3}_{2}	332.3333	C^{4}_{2}	332.3333		
C^{1}_{4}	332.3333	C^{2}_{4}	332.3333	C^{3}_{4}	332.3333	C^{4}_{3}	332.3333		
Network traffic				Surplus					
Q^{11}	0.0000	Q^{22}	3988.0000	Producer surplus				0.0000	
Q^{12}	0.0000	Q^{21}	0.0000	Consumer Surplus				232.4857	
				Social Welfare				232.4857	

Is obtained that the consumers freely choose to become subscribers of company 2, showing symmetric call patterns within them. In this situation, company 1 is out of the market, company 2 profits are cero, where each consumer makes 332 calls to each other, and consumer surplus and Social Welfare reaches 232.4857 (measured in monetary units). In Table 1.4 we compute the equilibrium for the case where the consumers are offered the chance only to become members of network 1, what is achieved in the model by setting a huge fixed cost to become subscriber of company 2 that in practice makes that all the consumers freely choose, if any, to become subscribers of company 1. If the huge fixed cost is suppressed we have that consumers rather move to company 2. In the equilibrium outcome of Table 1.4 the consumers also show symmetric call patterns within them. Comparing Consumer Surplus and Social Welfare within Table 1.3 and Table 1.4 we have that when the consumers are restricted only to become subscribers of company 1 Consumers Surplus and Social Welfare increases respect to the case where the consumers are free to choose to become subscribers of company 1 or company 2. In Table 1.4 company 2 is out of the market and company 1 serves all market demand and Social Welfare reaches 260.1516. Thus in the case where consumers are restricted only to become members of network 1, Social Welfare increases. This result shows that in a competitive market with prices adjusted to costs where consumers freely choose with whom they subscribe the telecommunication service, and where telecommunication companies can freely enter the market, there is no guarantee that decentralize agent decisions will lead to an efficient development of the market.[17]

Table 1.4
Experiment 1.- Outcome – Consumers are offered the chance only to become members of network 1

Consumer results								Company Profits	
I^{11}	1	I^{21}	1	I^{31}	1	I^{41}	1		
I^{12}	0	I^{22}	0	I^{32}	0	I^{42}	0	π^{1}	0.0000
C^{1}_{2}	665.6667	C^{2}_{1}	665.6667	C^{3}_{1}	665.6667	C^{4}_{1}	665.6667	π^{2}	0.0000
C^{1}_{3}	665.6667	C^{2}_{3}	665.6667	C^{3}_{2}	665.6667	C^{4}_{2}	665.6667		
C^{1}_{4}	665.6667	C^{2}_{4}	665.6667	C^{3}_{4}	665.6667	C^{4}_{3}	665.6667		
Network traffic				Surplus					
Q^{11}	7988.0000	Q^{22}	0.0000	Producer surplus				0.0000	
Q^{12}	0.0000	Q^{21}	0.0000	Consumer Surplus				260.1516	
				Social Welfare				260.1516	

But, why when the consumers can freely choose if they want to become subscribers of company 1 or company 2 we can not guarantee an efficient resource allocation?

With preference parameter values as in Table 1.1, we have that for the consumers company 1 network is a perfect substitute for company 2 network. But even thought prices have been set equal to marginal costs, we have that when consumers are free to choose if they want to contract telecommunication service with company 1 or company 2, consumers' incentives are not aligned with social incentives, an leads consumers to subscribe to a company that dictate to an inefficient development of the telecommunication industry. In the particular case analyzed, is cheaper to make calls within network 1 than within network 2 ($P^{11} < P^{22}$), and is cheaper to call from network 1 to network 2 than from network 2 to network 1 ($P^{12} < P^{21}$). With this, we should expect the consumers to contract telecommunication service with company 1. But if we expect that, someone can free ride on the other agents decision by contracting the telecommunication service with company 2 and getting by that a cheaper price to call the others that are expected to be in company 1 ($P^{21} < P^{11} < P^{22}$). However, we will have that all end behaving in the same manner and contracting telecommunication services with company 2 what at last leads to an inefficient resource allocation. Thus, while social incentive is to contract telecommunication services with company 1, individually by the lack of coordination the incentive is to contract telecommunication services with company 2, meaning that social and private incentives go in different directions and that leads to an inefficient resource allocation. The preceding happen even there is no externality from receiving a call. Basically, we have a Prisoner's Dilemma in the network choice game.

[17] Liebowitz and Margolis, (1998).

Call taste parameters

How different taste parameters to call or being called affect market equilibrium. Instead of using taste parameters ϕ^i_j = 1, *i*, *j* = 1,…,N, as in Table 1.1, in Table 1.5 we compute model equilibrium using taste parameters ϕ^i_j = 0,01, *i*, *j* = 1,…,N. Again, all the consumers become subscribers of company 2, where Social Welfare reaches 159.0142. Even though in the equilibrium a pattern of differentiated calls can emerge within the subscribers, where for the computed equilibrium consumer 1 free rides on consumers 2 to 4 incoming calls, consumer 2 free rides on consumers 3 and 4 incoming calls, and consumer 3 free rides on consumer 4 incoming calls.

Table 1.5
Experiment 1.- Outcome – Taste call preferences

Consumer results								Company Profits	
I^{11}	0	I^{21}	0	I^{31}	0	I^{41}	0		
I^{12}	1	I^{22}	1	I^{32}	1	I^{42}	1	π^1	0.0000
C^1_2	000.000	C^2_1	233.3333	C^3_1	233.3333	C^4_1	233.3333	π^2	0.0000
C^1_3	000.000	C^2_3	000.000	C^3_2	233.3333	C^4_2	233.3333		
C^1_4	000.000	C^2_4	000.000	C^3_4	000.000	C^4_3	233.3333		
Network traffic				Surplus					
Q^{11}	0000.000	Q^{22}	1,400.000	Producer surplus				0.0000	
Q^{12}	0000.000	Q^{21}	0000.000	Consumer Surplus				159.0142	
				Social Welfare				159.0142	

Table 1.6
Experiment 1.- Outcome – Taste call preferences when consumers are offered the chance only to become members of network 1

Consumer results								Company Profits	
I^{11}	1	I^{21}	1	I^{31}	1	I^{41}	1		
I^{12}	0	I^{22}	0	I^{32}	0	I^{42}	0	π^1	0.0000
C^1_2	000.000	C^2_1	566.6667	C^3_1	566.6667	C^4_1	566.6667	π^2	0.0000
C^1_3	000.000	C^2_3	000.000	C^3_2	566.6667	C^4_2	566.6667		
C^1_4	000.000	C^2_4	000.000	C^3_4	000.000	C^4_3	566.6667		
Network traffic				Surplus					
Q^{11}	3,400.000	Q^{22}	0000.000	Producer surplus				0.0000	
Q^{12}	0000.000	Q^{21}	0000.000	Consumer Surplus				187.5724	
				Social Welfare				187.5724	

In Table 1.5 within network 2 traffic drops respect to Table 1.3 outcome, what is explained by the fact that calls benefits comes largely from the calls received and not from the calls made, where the calls received are an externality from those who makes calls to those who receives them. The consumers freely choose to become subscribers of company 2, with asymmetric call patterns within them. In this situation, company 1 is out of the market, company 2 profits are cero, and consumer surplus and Social Welfare reaches 159.0142. However, as in Table 1.4, in Table 1.6 if the consumers are offered the chance only to become members of network 1, by making very expensive to be a subscriber of company 2, Social Welfare increases to 187.5724, and also traffic increases.

Technical innovation

Now and respect to Table 1.1 parameter values, assume that there is a technical innovation in company 2 such that company 2 call termination marginal cost decreases from 0.008 to 0.003. With that we have that the cost of calling within network 1 is the same as the cost of calling within network 2 (0.005), and is cheaper to call from network 2 to network 1 (0.004), than from network 1 to network 2 (0.006). Thus, if prices are adjusted to costs, in Table 1.7 we compute model equilibrium when c^{2e} = 0.03. Consumers become subscribers of company 2, where Social Welfare reaches 260.1516. Giving the same outcome as in Table 1.4 where consumers are allowed only to become subscribers of company 1.

Thus, under a CPP pricing policy regime, is more convenient for the consumers to become subscribers of company 2 because from this company they face the lowest prices to make calls to the other consumers no matter in which company the others are subscribers.

Here $c^{1e} < c^{2e}$ and in spite of everything is better if the consumers contract telecommunication services with company 2. Armstrong (2002) reaches to a result that differs from us, where he stays that the 1^rst^ Best is to have that prices should be set to attract consumers to the network with the lowest termination costs, but in our case higher efficiency is reached by attracting consumers to the network with the overall lower costs.

Table 1.7
Experiment 1.- Outcome – Technical change

Consumer results								Company Profits	
I^{11}	0	I^{21}	0	I^{31}	0	I^{41}	0		
I^{12}	1	I^{22}	1	I^{32}	1	I^{42}	1	π^1	0.0000
C^1_2	665.6667	C^2_1	665.6667	C^3_1	665.6667	C^4_1	665.6667	π^2	0.0000
C^1_3	665.6667	C^2_3	665.6667	C^3_2	665.6667	C^4_2	665.6667		
C^1_4	665.6667	C^2_4	665.6667	C^3_4	665.6667	C^4_3	665.6667		
Network traffic				Surplus					
Q^{11}	0000.000	Q^{22}	7,988.000	Producer surplus				0.0000	
Q^{12}	0000.000	Q^{21}	0000.000	Consumer Surplus				260.1516	
				Social Welfare				260.1516	

3.2.- Experiment 2.- Optimal tariff adjustment

If companies have a fixed cost in which they incur to provide the call origination and/or termination service, how we should adjust prices to account for the fixed cost such that the companies obtain enough revenues to cover all their costs while achieves higher social welfare?[18] To answer this question under different price policies we compute the equilibrium using a common parameter values set. Consumers are free to choose if they contract telecommunication services with company 1 or company 2.

[18] We are not looking up for Ramsey formulas that in real situations are difficult to apply because the lack of knowledge of demand elasticity. Instead of that, we assess simple and ad-hock tariff adjustment criteria's that has been suggested for Chilean telecommunication tariffs.

Table 2.1 present the preference, income, and cost parameter values set that we use for this experiment. From consumer preference and income parameter values we have that consumers are heterogeneous in terms of their likely of becoming subscribers of company 1 or company 2 according to their preference parameter $v^i(t)$, i =1,…,4, t=1,…,T. Thus, in terms of their preference parameter values they perceive network 1 not as a perfect substitute for network 2. Further, since $\phi^i_j = 1$, i, j = 1,…,N, the consumers only receive utility from the calls that they make but receive no utility from the calls that they receive. In terms of the cost structure, each company face a fixed or common cost $C^1 = C^2 = 1$, and are equally efficient in the cost of originating a call $c^{1o} = c^{2o}$ and in the cost of ending a call $c^{1e} = c^{2e}$, where $c^{io} > c^{ie}$, i = 1,2.

Table 2.1 Experiment 2.- Technology and Preference Parameters										
Technology		Preferences								
c^{1o}	0.003	Consumer	1		2		3		4	
c^{1e}	0.002	v^{i1}	1.000		0.900		0.800		0.700	
c^{2o}	0.003	v^{i2}	0.700		0.800		0.900		1.000	
c^{2e}	0.002	g^i	0.300		0.300		0.300		0.300	
C^1	1.000	m^i	10.000		10.000		10.000		10.000	
C^2	1.000		ϕ^1_2	1.000	ϕ^2_1	1.000	ϕ^3_1	1.000	ϕ^4_1	1.000
			ϕ^1_3	1.000	ϕ^2_3	1.000	ϕ^3_2	1.000	ϕ^4_2	1.000
			ϕ^1_4	1.000	ϕ^2_4	1.000	ϕ^3_4	1.000	ϕ^4_3	1.000

First assume that prices are set equal to marginal costs and for each company is set an access charge T^i to account for the fixed or common cost, where T^i is set equal to the fixed or common cost of company i divided by company i number of subscribers, namely the average fixed cost (AFC). The price policy for this case is given in Table 2.2.[19]

Table 2.2 Experiment 2.- Prices – Adjustment on T^i		
P^{11}	0.0050	= MgC
P^{12}	0.0050	= MgC
P^{22}	0.0050	= MgC
P^{21}	0.0050	= MgC
p^{1o}	0.0030	= MgC
p^{1e}	0.0020	= MgC
p^{2o}	0.0030	= MgC
p^{2e}	0.0020	= MgC
T^1	0.5000	= AFC
T^2	0.5000	= AFC

For the pricing policy of Table 2.2, where T^i is adjusted to account for the fixed cost, Table 2.3 gives equilibrium outcome. Consumers 1 and 2 become subscribers of company 1, while consumers 3 and 4 become subscribers of company 2.

Table 2.3 Experiment 2.- Outcome - Adjustment on T^i				

[19] A pricing policy like this can emerge as a part of a Competitive Equilibrium, as defined in 2.3, or an Equilibrium with the companies competing in prices.

Consumer results								Company Profits	
I^{11}	1	I^{21}	1	I^{31}	0	I^{41}	0		
I^{12}	0	I^{22}	0	I^{32}	1	I^{42}	1	π^1	0.0000
C^1_2	665.6667	C^2_1	599.0000	C^3_1	599.0000	C^4_1	665.6667	π^2	0.0000
C^1_3	665.6667	C^2_3	599.0000	C^3_2	599.0000	C^4_2	665.6667		
C^1_4	665.6667	C^2_4	599.0000	C^3_4	599.0000	C^4_3	665.6667		
Network traffic				Surplus					
Q^{11}	1264.6667	Q^{22}	1264.6667	Producer surplus				0.0000	
Q^{12}	2529.3333	Q^{21}	2529.3333	Consumer Surplus				245.2505	
				Social Welfare				245.2505	

From the equilibrium we have that the consumers that benefit more from telecommunication services (consumer 1 in company 1 and consumer 4 in company 2) make more calls than those who benefit less from telecommunication services (consumer 2 in company 1 and consumer 3 in company 2). Since usage prices are equal, $P^{11} = P^{12} = P^{22} = P^{21}$, and because $\phi^i_j = 1$, $i, j = 1,\ldots,N$, a consumer makes the same number of calls to the other consumers with independence of the company in which the other has contracted the service. For the equilibrium computed in Table 2.3 companies incurs no losses, and consumer surplus equals Social Welfare of 245.2505.

In Table 2.4 we sketch a different price policy regime, where T^1 and p^{1e} are adjusted to account for company 1 fixed or common cost, and T^2 is adjusted to account for company 2 fixed or common cost. Company 1 termination charge p^{1e} is arbitrarily increased in 0.00011 above marginal cost, and with that the price to call within company 1 network P^{11} and to call from company 2 network to company 1 network P^{21} increases in 0.00011 above the respective service marginal cost. Then T^1 is chosen such that at the equilibrium company 1 profits are cero. On the other side company 2 access price T^2 is set equal to the fixed or common cost of company 2 divided by company 2 number of subscribers, namely the average fixed cost (AFC).

Table 2.4 Experiment 2.- Prices – Adjustment on T^1, p^{1e} and T^2		
P^{11}	0.00511	> MgC
P^{12}	0.00500	= MgC
P^{22}	0.00500	= MgC
P^{21}	0.00511	> MgC
p^{1o}	0.00300	= MgC
p^{1e}	0.00211	> MgC
p^{2o}	0.00300	= MgC
p^{2e}	0.00200	= MgC
T^1	0.30000	< AFC
T^2	0.50000	= AFC

For the pricing policy of Table 2.4, where T^1 and p^{1e} and T^2 are adjusted to account for the fixed costs, Table 2.5 gives equilibrium outcome. Again consumers 1 and 2 become subscribers of company 1, while consumers 3 and 4 become subscribers of company 2.

Table 2.5 Experiment 2.- Outcome - Adjustment on T^1, p^{1e} and T^2									
Consumer results								Company Profits	
I^{11}	1	I^{21}	1	I^{31}	0	I^{41}	0		
I^{12}	0	I^{22}	0	I^{32}	1	I^{42}	1	π^1	0.0000

C^1_2	651.6088	C^2_1	586.3479	C^3_1	586.3479	C^4_1	651.6088	π^2	0.0000
C^1_3	665.6667	C^2_3	599.0000	C^3_2	586.3479	C^4_2	651.6088		
C^1_4	665.6667	C^2_4	599.0000	C^3_4	599.0000	C^4_3	665.6667		
Network traffic				Surplus					
Q^{11}	1237.9568	Q^{22}	1264.6667	Producer surplus				0.0000	
Q^{12}	2529.3333	Q^{21}	2475.9135	Consumer Surplus				245.2463	
				Social Welfare				245.2463	

We have once more from the equilibrium that the consumers that benefit more from telecommunication services (consumer 1 in company 1 and consumer 4 in company 2) make more calls than those who benefit less from telecommunication services (consumer 2 in company 1 and consumer 3 in company 2). Now since usage prices are not equal, $P^{11} = P^{21} > P^{12} = P^{22}$, and $\phi^i_j = 1$, $i, j = 1,\ldots,N$, consumer makes different numbers of calls to those subscribers that can be reached at a low or a high usage price, making less calls to the lasts. For the equilibrium computed in Table 2.5 companies incurs no losses, and consumer surplus equals Social Welfare of 245.2463.

Comparing the equilibrium results from Table 2.3 and Table 2.5 we obtain that Social Welfare is larger when the revenues required to finance companies fixed or common costs are collected by a telecommunication service fixed access charge instead of collecting part of the required revenues by increasing the companies termination charge p^{it} above marginal cost.

3.3.- Experiment 3.- Network interconnection charge differences transferred to the public

If the companies have different interconnection charges for the use of their network, should interconnection charge differences be transferred to the public, or interconnection charges should be made equal between the different companies?, and if they are made equal, what are the effects of doing them equal to the cost of the company with the lowest interconnection cost, or equal to the cost of the company with the largest interconnection cost?

To answer this questions and for different interconnection charge policies we compute model equilibrium with a particular parameter values set, where the consumers are free to choose if they can contract telecommunication services with company 1 or company 2. These allow us to compare the efficiency properties of the equilibrium under the alternative interconnection charge policies.

Table 3.1
Experiment 3.- Technology and Preference Parameters

Technology		Preferences								
c^{1o}	0.003	Consumer	1		2		3		4	
c^{1e}	0.002	v^{i1}	1.000		0.900		0.800		0.700	
c^{2o}	0.004	v^{i2}	0.700		0.800		0.900		1.000	
c^{2e}	0.003	g^i	0.300		0.300		0.300		0.300	
C^1	1.000	m^i	10.000		10.000		10.000		10.000	
C^2	1.000		ϕ^1_2	1.000	ϕ^2_1	1.000	ϕ^3_1	1.000	ϕ^4_1	1.000
			ϕ^1_3	1.000	ϕ^2_3	1.000	ϕ^3_2	1.000	ϕ^4_2	1.000
			ϕ^1_4	1.000	ϕ^2_4	1.000	ϕ^3_4	1.000	ϕ^4_3	1.000

Table 3.1 present the preference, income, and cost parameter values set that we use for this experiment. From consumer preference and income parameter values we have that consumers are heterogeneous in terms of their likely of becoming subscribers of company 1 or company 2 according to their preference parameter $v^i(t)$, i =1,…,4, t=1,…,T. Thus, in terms of their preference parameter values they perceive network 1 not as a perfect substitute for network 2. Further, since ϕ^i_j = 1, i, j = 1,…,N, the consumers only receive utility from the calls that they make but receive no utility from the calls that they receive. In terms of the cost structure, each company face a fixed or common cost $C^1 = C^2 = 1$, and company 1 is more efficient than company 2 in the cost of originating a call $c^{1o} < c^{2o}$ and in the cost of finishing a call $c^{1e} < c^{2e}$. Further, in each company the cost of finishing a call is lower than the cost of originating a call $c^{ie} < c^{io}$, i = 1, 2.

As benchmark first we compute equilibrium where interconnection charges are adjusted to costs, and where interconnection charge differences are transfer to the public. For this benchmark case the basic usage prices are defined as

$$P^{11} = c^{1o} + c^{1e}$$
$$P^{12} = c^{1o} + p^{2e}$$
$$P^{22} = c^{2o} + c^{2e}$$
$$P^{21} = c^{2o} + p^{1e}$$
$$p^{1o} = c^{1o}$$
$$p^{2o} = c^{2o}$$
$$p^{1e} = c^{1e}$$
$$p^{2e} = c^{2e}$$

Therefore, for the model parameter values, in Table 3.2 are the prices used for benchmark model where interconnection charge differences are transferred to the public.

Table 3.2 Experiment 3.- Prices – Interconnection charges adjusted to costs		
P^{11}	0.0050	= MgC
P^{12}	0.0060	= MgC
P^{22}	0.0070	= MgC
P^{21}	0.0060	= MgC
p^{1o}	0.0030	= MgC
p^{1e}	0.0020	= MgC
p^{2o}	0.0040	= MgC
p^{2e}	0.0030	= MgC
T^1	0.5000	= AFC
T^2	0.5000	= AFC

For the pricing policy of Table 3.2, where interconnection charges are adjusted to costs, Table 3.3 gives equilibrium outcome. Consumers 1 and 2 become subscribers of company 1, while consumers 3 and 4 become subscribers of company 2.

Table 3.3 Experiment 3.- Outcome – Interconnection charges adjusted to costs									
Consumer results								Company Profits	
I^{11}	1	I^{21}	1	I^{31}	0	I^{41}	0		
I^{12}	0	I^{22}	0	I^{32}	1	I^{42}	1	π^1	0.0000

C^1_2	665.6667	C^2_1	599.0000	C^3_1	499.0000	C^4_1	554.5556	π^2	0.0000
C^1_3	554.5556	C^2_3	499.0000	C^3_2	499.0000	C^4_2	554.5556		
C^1_4	554.5556	C^2_4	499.0000	C^3_4	427.5714	C^4_3	475.1905		
Network traffic				Surplus					
Q^{11}	1264.6667	Q^{22}	902.7619	Producer surplus				0.0000	
Q^{12}	2107.1111	Q^{21}	2107.1111	Consumer Surplus				238.5127	
				Social Welfare				238.5127	

From the equilibrium we have that the consumers that benefit more from telecommunication services (consumer 1 in company 1 and consumer 4 in company 2) make more calls than those who benefit less from telecommunication services (consumer 2 in company 1 and consumer 3 in company 2). Since usage prices are different, $P^{11} < P^{12} = P^{21} < P^{22}$, and because $\phi^i_j = 1$, $i, j = 1,\ldots,$N, each consumer makes different number of calls to the other consumers depending on the price that she/he faces for doing the call, what depends on the interconnection charge paid by one company to the other. For the equilibrium computed in Table 3.3 the companies incur no losses, and consumer surplus equals Social Welfare of 238.5127.

In Table 3.4 we sketch a different price policy, where company 2 interconnection charge p^{2e} is set equal to company 1 interconnection charge p^{1e}, where $p^{1e} = c^{1e} < c^{2e}$. Since company 2 is providing interconnection to his network at a price that is below the marginal cost, is required an increase in the price of other services of the company, where arbitrarily we increase T^2 above the average fixed cost until in the equilibrium the company 2 cover all his cost. Otherwise company 2 will not be able to operate in the market. Other prices are set equal to their marginal costs except for P^{12} that decreases with p^{2e}, and with T^1 that is set equal to company 1 average fixed cost.

Table 3.4 Experiment 3.- Prices – Network 2 interconnection charges below Marginal Cost		
P^{11}	0.0050	= MgC
P^{12}	0.0050	< MgC
P^{22}	0.0070	= MgC
P^{21}	0.0060	= MgC
p^{1o}	0.0030	= MgC
p^{1e}	0.0020	= MgC
p^{2o}	0.0040	= MgC
p^{2e}	0.0020	< MgC
T^1	0.5000	= AFC
T^2	1.76465	> AFC

For the pricing policy of Table 3.4, where interconnection charge of company 2 is below marginal cost, Table 3.5 gives equilibrium outcome. Consumers 1 and 2 become subscribers of company 1, while consumers 3 and 4 become subscribers of company 2.

Table 3.5 Experiment 3.- Outcome– Network 2 interconnection charges below Marginal Cost									
Consumer results								Company Profits	
I^{11}	1	I^{21}	1	I^{31}	0	I^{41}	0		
I^{12}	0	I^{22}	0	I^{32}	1	I^{42}	1	π^1	0.0000

C^1_2	665.6667	C^2_1	599.0000	C^3_1	499.0000	C^4_1	554.5556	π^2	0.0000
C^1_3	665.6667	C^2_3	599.0000	C^3_2	499.0000	C^4_2	554.5556		
C^1_4	665.6667	C^2_4	599.0000	C^3_4	427.5714	C^4_3	475.1905		
Network traffic				Surplus					
Q^{11}	1264.6667	Q^{22}	902.7619	Producer surplus				0.0000	
Q^{12}	2529.3333	Q^{21}	2107.1111	Consumer Surplus				238.2888	
				Social Welfare				238.2888	

For the equilibrium computed in Table 3.5 the companies incur no losses, and consumer surplus equals Social Welfare of 238.2888, what is below the social welfare that is achieved in the previous benchmark case of 238.5127. Thus, in this scenario where we set interconnection charges equal to the cost of the company with lowest interconnection cost, decreases social welfare even though the telecommunication service fixed interconnection charge of the company with higher termination costs is increased in a way such that in equilibrium it incur no losses.

In Table 3.6 the price policy is one where company 1 interconnection charge p^{1e} is set equal to company 2 interconnection charge p^{2e}, where $p^{2e} = c^{2e} > c^{1e}$. Since company 1 is providing interconnection to his network at a price that is above the marginal cost, the price of other services of the company can be decreased, where arbitrarily we decrease T^1 below the average fixed cost down to cero, where in equilibrium company 1 still obtain strictly positive profits. Other prices are set equal to their marginal costs except for p^{21} that increases with p^{1e}, and with T^2 that is set equal to company 2 average fixed cost.

Table 3.6 Experiment 3.- Prices – Network 1 interconnection charges above Marginal Cost		
P^{11}	0.0050	= MgC
P^{12}	0.0060	= MgC
P^{22}	0.0070	= MgC
P^{21}	0.0070	> MgC
p^{1o}	0.0030	= MgC
p^{1e}	0.0030	> MgC
p^{2o}	0.0040	= MgC
p^{2e}	0.0030	= MgC
T^1	0.0000	< AFC
T^2	0.5000	= AFC

For the pricing policy of Table 3.6, where interconnection charges of company 1 is above marginal cost, Table 3.7 gives equilibrium outcome. Consumers 1 and 2 become subscribers of company 1, while consumers 3 and 4 become subscribers of company 2.

Table 3.7 Experiment 3.- Outcome – Network 1 interconnection charges above Marginal Cost									
Consumer results								Company Profits	
I^{11}	1	I^{21}	1	I^{31}	0	I^{41}	0		
I^{12}	0	I^{22}	0	I^{32}	1	I^{42}	1	π^1	0.8055
C^1_2	665.6667	C^2_1	599.0000	C^3_1	427.5714	C^4_1	475.1905	π^2	0.0000
C^1_3	554.5556	C^2_3	499.0000	C^3_2	427.5714	C^4_2	475.1905		
C^1_4	554.5556	C^2_4	499.0000	C^3_4	427.5714	C^4_3	475.1905		
Network traffic				Surplus					

Q^{11}	1264.6667	Q^{22}	902.7619	Producer surplus	0.8055
Q^{12}	2107.1111	Q^{21}	1805.5238	Consumer Surplus	238.3697*
				Social Welfare	238.3697
Consumer surplus accounts for the dividends received from the companies profits. Without dividends, consumer surplus reaches 237.5642					

For the equilibrium computed in Table 3.7 company 1 obtain positive profits, company 2 incur no losses, and consumer surplus plus company 1 profits gives Social Welfare of 238.3697, what is below the Social Welfare that is achieved in the benchmark case of 238.5127, but above Social Welfare of 238.2888 achieved in the previous case where interconnection charges are set equal to the lowest call termination cost.

4.- Conclusion

In this paper we develop a General Equilibrium model where agents choose the telecommunication company and the number of calls they made to other subscribers. The consumers benefit from the calls that they do but also from the calls they receive. Based on equilibrium properties and with numerical experiments under specific parameter values sets we address three important questions that continuously appear in the debate about interconnection charges: consumers network choice will lead to an optimal development of the industry?; if telecommunication companies confront a fixed or common cost, what price adjustment gives a larger social welfare?; when the regulator calculates termination or interconnection charges into the different telecommunication networks, the interconnection charges should be equal or different for the different networks?, and if they are different, what are the effects that the differences in interconnection charges are or not transfer to the public or final user?

First, we obtain that social and private incentives may go in different directions, implying that competitive equilibrium may lead to an inefficient network selection and an inefficient resource allocation. That is, agents' network decision leads to an inefficient industry structure because they competitively chose a network that from a social point of view is an inferior one. Second, we find that Social Welfare is larger when the revenues required to finance companies fixed or common costs are collected by a fixed access charge instead of collecting part of the required revenues by increasing the companies' interconnection charge above marginal cost. If telecommunication companies faces a fixed or common cost, becomes of higher efficient to finance this cost through a fixed access charge on the telephone line, setting telecommunication companies interconnection charges equal to each company interconnection marginal cost, where policies that finance fixed or common costs by increasing interconnection charges above marginal costs lead to a less efficient allocation than policies where telecommunication companies interconnection charges is set equal to the interconnection marginal cost, of the company with the highest or lowest interconnection marginal cost. Finally and third, for the equilibrium computed if the companies' interconnection costs are different, efficiency calls to set interconnection charges equal to each company interconnection marginal cost and to transfer interconnection charge differences to the public.

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