Vertical Product Differentiation, Network Competition and Regulation of Connectivity

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May 2001

JEL Classification: L13, L15, L51

Abstract: In this paper competition between two network firms is analysed under two alternative regulatory regimes: a global connectivity regulation (*GCR*) and an efficient component pricing regulation (*ECPRe*). Whereas a GCR imposes a full quality of reciprocal interconnection, firms will choose vertical product differentiation in order to lower price competition, while under a ECPRe they will choose the maximum level of services quality and a global degradation of connectivity. Hence firms' decisions about whether or not vertically differentiate products seems to be, at least partially, related to regulatory rules imposed on the market.

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1. Introduction[1]

The economic literature on networks is currently so extensive[2] that it's no more futile, as a starting point, an attempt to clarify in which framework our analysis will be set. Many relevant issues will not actually enter in our discussion, even if a large debate on them is going on among economists.

From a very early paper by Rohlfs (1974) a day by day growing amount of contributions on networks has tried to capture different economic features of this idea changing perspective where necessary.

Formally networks are always modelled as a set of links which connect several nodes independently on the specific sense given to links and nodes in different contexts. Then a theoretical preliminary problem is to understand how these links can be built and what is, if it exists, an efficient outcome of a link formation game. In a very general set up, with an arbitrary number of individuals, Jackson and Wolinsky (1996) analyse efficiency and stability of networks formed by self-interested agents who choose their different links to others. In more specific frameworks, *inter alia*, Zhang (1995) studies network formation choices undertaken by firms which have to sell goods in different cities, Hendricks et al. (1999) examine equilibria in link formation games for the case of airlines routes and Kranton and Minehart (1998) study efficient results of a link formation game in a two-sided market where a network is seen as a system for exchanging goods. In what follows we will not discuss these kinds of problems assuming an efficient outcome has raised from a previously played link formation game.

A particularly rich literature has devoted her attention on networks not seen as set of bilateral relations among individuals[3], but as a structure that relates many technological components which are required to provide a certain service (among the others Katz and Shapiro (1985), Farrell and Saloner (1986), Economides (1996)). This approach has lead to many significant results related to issues on compatibility, interoperability and co-ordination among different networks. These authors have studied problems of social optimality in network

[1] I would like to thank Salvador Barberà, Vincenzo Denicolò, Luis Cabral, Luca Lambertini, Xavier Martìnez-Giralt and Jodi Massò for useful comments and observations on a preliminary version of the paper. A research scholarship from The Bank of Italy is also gratefully acknowledged. Obviously usual disclaimers are applied.
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[2] For an almost complete bibliography see Edgard Stern's web page: *www.edgar.stern.nyu.edu/networks/bibliography.html*
[3] For a reference on a more sociologic approach see Wellman and Berkowitz (1988)'s survey.

interconnection and possible peculiarities of competition in network industries[4]. The main common idea of these contributions is that a *network effect,* related with network externalities, exists and, if sufficiently strong it can modify optimal conduct of profit maximising firms. Any attempt to analyse network industries must take into account this effect in order to be realistic; as we will see our model will consider a simple version this effect.

Another quite wide research field has studied competition among firms which can choose a certain price-quantity combination for their services simultaneously with an efficient network structure. When a firm can choose different ways to link two nodes in his network, it's meaningful to search the most efficient network structure that allows a service provider to be more competitive and to obtain a larger market share and higher profits. In this view, a network structure can be changed in order to exploit *economies of density* which can reduce average costs and hence prices. Applications of this concepts fit particularly well in modelling airline network rivalry (e.g. Oum et al. (1995), Brueckner and Spiller (1991), Brueckner et al. (1992)) or internal organisation of firms (e.g. Keren and Levhari (1983)). However a networks structure not always can be easily modified: telecommunication networks, for instance, require very high costs for a change in their structure and this suggests to build it optimally once and to not modify them frequently. In other words, we can say that airlines networks are quite peculiar because of their low alteration costs differently from other networks. In what follows, we will refer to sectors in which these costs are very high and it's not possible to change an optimally built network.

Finally, we will suppose that different networks are owned by different firms which use them for providing a certain service; this assumption rules out problem of public regulation of access to a unique network managed by an central input monopolist for actual or potential competitors (e.g. Laffont and Tirole (1994), Amstrong et al. (1996)), and it allows us to focalise attention on competition between network operators who sell substitutes services. In this way our model could be applied to liberalised telecommunication markets and commercial internet markets [5].

2. Interconnection and Quality in Network Industries

[4] Again only for a general reference see Economides and Salop (1992), Bental and Spiegel (1995) and Cabral et al. (1999).
[5] Some recent contributions have tried to study the so called *Economics of Internet* see for example Baileys (1995), McKie-Mason and Varian (1996) and Coates (1998) all available on the net.

In the last years the increasing economic role and weight of network industries has raised several questions about how these industries operate, in which way using a particular input as a network can modify competition among firms or what are strategic variables which can be manipulated by a firm.

Starting from the well studied problem of the access of potential competitors to a single network owned by a firm (Laffont and Tirole (1996)), a crucial role was recognised to interconnection and access pricing practices. The unit price of interconnection to a common network can influence competitors costs and it can be used like an anticompetitive tool, or a discriminatory device, in advantage of vertically related or cross owned firms.

Hence, a natural step forward has been to analyse the case of two firms, each with her own network, which compete in the same market. Any firm manages a network of a given extension formed by the number of attached consumers and provides services (as telephony, data transmission, internet services etc.) basically connecting different nodes of her network. Some of these services are on-net in the sense that they are completed inside the owned network while some others may pass through other firm's network connecting an on-net node with an off-net one. In this last case an access price must be paid to competitors which offer interconnection with their attached consumers.

In a fairly quoted model of horizontal differentiation in which price discrimination among *on net* and *off net* servicies is not allowed, Laffont, Rey and Tirole (1998) have shown that access charges are an instrument of tacit collusion in the case of a reciprocal access pricing agreement. Additionally in the case of noncooperative access charges, they are a way to increase competitor retail prices. Moreover whether the degree of substitutability of two services is very high or for high access charges, each firm has incentive to corner the market and an internal Hotelling equilibrium does not exist. Similarly, Carter and Wright (1999) have proved, again in a Hotelling set up, that symmetric firms can effectively collude over retail prices by colluding over access tariffs. Furthermore both firms can gain higher profits from full reciprocal interconnection seen as a result of a Nash bargaining problem with no interconnection as the disagreement point. In both models access tariffs are crucial strategic variables that can or cannot be subjected to public regulation. The competitive game is characterised by manipulations of prices (and then quantities) and access charges given a certain firms' location.

Nevertheless relatively few models have tried to introduce into the analysis a quality dimension of connectivity. In fact it seems reasonable and realistic to suppose that a firms can concede to a rival different quality levels of interconnection in terms of compatibility of standards or interface capacity[6]. This possibility is studied by Cremer, Rey and Tirole (2001) in a context of oligopolistic competition between internet backbones; in a two stage game, where firms first set the quality of interconnection then they choose capacities and prices, symmetric size firms will choose high quality of reciprocal interconnection while, in case of asymmetry, a dominant firm will prefer a lower quality of interconnection with a small rival. Furthermore, the latter quality will be lower the higher her total installed base (i.e.attached consumers) is and the smaller are benefits from network externalities (i.e. rival's attached consumers). Thus, an additional strategic variable becomes relevant and it can be used as an anticompetitive weapon[7]. Bental and Spiegel (1995) are arrived to a similar result modelling quality competition among firms, where quality of a network is identified with the number of attached consumers (i.e. network externalities dimension of quality). In their model a slightly different problem of compatibility is studied, but the basic intuition of their result is quite similar to Crémer et al.(1999)'s one: incompatibility is a tool to restrict the market for a dominant firm.

As best as we know, no contributions have tried to deal with another dimension of quality related to supplied network services. As rightly noticed by Crémer and Hariton (1999) with respect to internet services, we can recognise at least two quality levels for network services: low quality services with dial-up connection and small bandwidth and high quality ones with permanent connection, high bandwidth, certified delivery times and secured transactions. This vertical differentiation of supplied services is justified by different consumer's preferences (light and heavy users) and it implies different prices. The same intuition can be easly applied to mobile telephony where we can recognise high quality services (written communication, data transfers, e-mail etc.) and low quality ones (basic voice communication). Hence, network firms can also compete offering differentiated contracts in terms of quality and price.

In what follows, we will build a three stage model of competition between two symmetric network firms which tries to deal either with problems of interconnection (in term of access prices and quality) or with vertical product differentiation. In the first stage firms decide interconnection agreements, in the second one they choose services'quality and then they

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[6] Low compatibility of standards may not allow certain services or small interface capacity can induce systematic delays or losses of packets.

[7] They show that a reduction of the quality of interconnection given to a targeted competitor (*targeted degradation strategy)* by a dominant backbone can generate a competitive advantage over the former firms, increasing dominant firm's profits and market share.

compete in prices. In doing this, we will take as a reference point the well known Shaked and Sutton's (1982) model of vertical product differentiation[8].

Our aim will be to study firms' behaviour under two alternatives regulatory regimes. We will assume that a regulator can establish a completely competitive interconnection agreement with high quality of interconnection, reciprocal access price and balanced flows between the two networks[9] or it can simply impose an Efficient Component Pricing rule for access tariffs. In the first regime a full-informed regulator wants to implement a set of rules for ensuring full, advanced interconnection among networks. In opposition, in our second case, the regulator has only general information about firms' costs and it can only set a tariff scheme in order to relate access charges to production costs. As we will see, firms' behaviour will be strongly modified by different regulatory frameworks.

The paper is organised as follows: in section 3 our model in introduced, in section 4 and 5 competition between two network firms is analysed under the previous two regulatory regimes. Section 6 summaries conclusions and compares our results.

3. The Model

In this section, we will model a duopolistic market where two symmetric firms compete for unattached consumers which have different preferences for quality. The two competitors have the same starting installed based, hence without loss of generality we can assume it equal to a positive number.

3.1 Demand side

In our economy there are heterogeneous unattached consumers $k = 1,...,K$ which buy one unit of network service each, obtaining a utility given by

$$U_k = \mathbf{d}\, s_n - p_n \qquad (1)$$

[8] In fact we will use a slight modification of this model proposed by Tirole (1988).

[9] In the rest of the paper let us refer to this case as *global connectivity regulation.*

where s_n is the quality level of the service provided by firm n =*i,j* at a price p_n and δ is a parameter of preference for quality that goes from δ, sufficiently high to ensure market coverage, to $\overline{\delta} = \underline{\delta} + 1$. The quality of services provided by firm *n* is given by[10]

$$s_n = \left(\overline{q}_n + \theta_{n-n}\overline{q}_{-n}\right) + \alpha_n \qquad (2)$$

with $\overline{q}_n$ the installed base of network n (i.e. the number of attached consumers enrolled by firm *n*), $\overline{q}_{-n}$the number of attached consumers which have signed a contract with the rival; $\theta_{n-n} \in [0;1]$ is interconnection quality that firm *n* concedes to firm -*n* and $\alpha_n \geq 0$ the hedonistic index related with the consumption of firm *n*'s services. Hence, the total quality of a service is given by a network externalities component (Katz and Shapiro (1985)) and by a product specific component in terms of kind of connection, delivery times etc. Under a null quality of interconnection $\left(\theta_{n-n} = 0\right)$ each consumer can very difficulty reach nodes on the other network, incurring in very high usage costs which nullify any network externalities component in s_n .

Let me denote the quality differential with $\Delta\alpha = \left|\alpha_n - \alpha_{-n}\right|$ and with $\overline{\Psi} = \overline{\delta}\Delta\alpha$,$\underline{\Psi} = \underline{\delta}\Delta\alpha$ respectively the maximum and the minimum monetary value of $\Delta\alpha$ for different consumers. As usual, we can impose some technical conditions on our parameters:

Assumption 1: In what follows we assume that

1. $\overline{\delta} \geq 2\underline{\delta}$
2. $c + \dfrac{\overline{\delta} - 2\underline{\delta}}{3}\Delta\alpha \leq \underline{\delta}\alpha_i$

where c is the marginal cost of producing one unit of service equal, given our symmetry assumption, for both firms.

Thus, an indifferent consumer will be characterised as:

$$\tilde{\delta} = \frac{p_{-n} - p_n}{\left(1-\theta_{n-n}\right)\overline{q}_{-n} - \left(1-\theta_{-nn}\right)\overline{q}_n + \alpha_{-n} - \alpha_n} \qquad (3)$$

[10] A similar characterisation is used by Crémer et al. (2000).

and he will be indifferent from buying a unit of service from the two firms compensating an higher price with higher quality; obviously the network externalities component will be irrelevant in determining such an indifference condition in case of high quality of reciprocal interconnection between firms.

3.2 Supply side

For the supply side, we have two symmetric network firms $n = i, j$ which compete for unattached consumers. Each consumer buys one unit of service. Hence, the quantity q_n represents both total number of firm's subscribers and total quantity sold in the market. Any enrolled customer can consume on-net or off-net services therefore each firm will have a proportion g_n of sold services that is completed inside her network and a proportion $1-g_n$ that must be completed by her rival. For completing rival's services, firm *n* charges an access price t_n to the other network firm and, symmetrically, firm *-n* does the same. Any unit of service has a symmetric constant marginal cost *c* identical for on-net or off-net one, that is the cost of a transit in firm *n*'s network. Hence, for a unit of off-net services a firm will pay the marginal cost of production and the access price. Giving access to a rival implies a cost of delivery equal to $d_n = q_{n-n}c$ where *c* is the marginal cost of on-net services and θ the quality of interconnection. Decreasing θ it will be lower the marginal cost of delivering rival's services[11]. Finally let we suppose that serving a consumer involves a fixed cost *f* normalised, for tractability, to zero and that price discrimination between on and off net services is not allowed.

The quantity sold by a firm depends on the quality s_i and the retail price p_i and firms' profit will be given by the sum of on-net profits $\Pi_n^{on} = g_n(p_n - c)q_n$, off-net ones $\Pi_i^{off} = (1-g_n)(p_n - c - t_{-n})q_n$ and profits obtained by giving access to the rival $\Pi_n^{acc} = (t_n - d_n)(1-g_{-n})q_{-n}$. Hence, for each network firm $n = i, j$ total profits are given by

$$\Pi_n = \left[p_n - c + (1-g_n)t_{-n}\right]q_n + (t_n - d_n)(1-g_{-n})q_{-n} \qquad (4)$$

With no regulation, it will maximise (4) with respect to p_n, q_{n-n}, t_n and a_n.

[11] We can reasonably think that a low quality of interconnection implies less priority and lower speed in transferring packets and hence a lower marginal cost.

In what follows, let we assume, for the sake of tractability, symmetric flows of services between networks, that is the same percentage of average outflow traffic generated by each firm's subscriber (i.e. $\gamma_n = \gamma$ for any n). Relaxing this assumption not only makes model results' difficulty interpretable, but also adds a possible diversification strategy for service providers: a different degree of specialisation in intra-network traffic and a consequently different quality dimension of services targeted to class of users which give different values to intra-network and inter-network traffic[12]. Since our first aim is to give some insights on possible effects' of regulation on network competition, symmetry with respect to this dimension does not alter too much our findings.

3.3 The Game

The competition between firms is described as a multistage game with complete information: in the first stage firms decide interconnection conditions fixing t_n and q_{n-n}, then they choose a certain quality for services a_n and, in the third stage, they compete in prices.

This structure seems consistent either with the spirit of Shaked and Sutton's type of models, or with an existing network firms' practice of signing periodically interconnection agreements[13]. Moreover, with an extensive form competitive game, we can simply introduce regulation on connectivity by setting quality of interconnection and access prices, thus reducing firms' decision problem to a two-stage game. As usual, we will use a backward induction procedure and we will derive subgame perfect Nash equilibria.

4. Vertical Differentiation under Global Connectivity Regulation

Let we suppose that a regulator imposes a *global connectivity regulation (GCR)* fixing quality of interconnection and reciprocal access charges. Firms set in the first stage of the game a certain level of quality for their services then they compete in prices. Using expression (3) and recalling that consumers are uniformly distributed on the interval $[\underline{d};\overline{d}]$ we can obtain firms' demands given by:

[12] For internet services different preferences about this quality dimension gives diversify users' demand of intra-domain traffic (i.e. e-marketplaces, closed-web services etc…) and end-to-end connection. This will induce different technical specialisation of networks and different marketing strategies for service providers. For a discussion of these issues see Blake et al. (1998), Odlyzko (2000) and, for a bussiness oriented view, Picardi (2000).

[13] For example Internet Protocol or Transfer Control Protocol.

$$
\begin{aligned}
D_i\left(p_i;p_j\right) &= \frac{p_j - p_i}{\left(1-\theta_{ij}\right)q_j - \left(1-\theta_{ji}\right)q_i + \alpha_j - \alpha_i} - \underline{\delta} \\
D_j\left(p_i;p_j\right) &= 1 - \frac{p_j - p_i}{\left(1-\theta_{ij}\right)q_j - \left(1-\theta_{ji}\right)q_i + \alpha_j - \alpha_i} + \underline{\delta}
\end{aligned} \tag{5}
$$

Obviously, it is possible, substituting (5) into profits, to derive profit functions in terms of prices and qualities:

$$
\begin{aligned}
\Pi_i &= \left[p_i - c + \left(1-\gamma_i\right)t_j\right]D_i\left(p_i;p_j\right) + \left(t_i - d_i\right)\left(1-\gamma_j\right)D_j\left(p_i;p_j\right) \\
\Pi_j &= \left[p_j - c + \left(1-\gamma_j\right)t_i\right]D_j\left(p_i;p_j\right) + \left(t_j - d_j\right)\left(1-\gamma_i\right)D_i\left(p_i;p_j\right)
\end{aligned} \tag{6}
$$

By construction, profits functions are twice continuously differentiable with bounded derivatives and concave. As noticed above, firms are usually able to manipulate quality of interconnection and/or access prices in order to gain higher profits using the access charge as an instrument of tacit collusion or as a tool to obtain larger market shares. However, this is not the case whereas a regulator imposes a particular interconnection agreement:

Definition 1: We define *Global Connectivity Regulation (GCR)* a regulatory regime where reciprocal access $\left(t_i = t_j = t\right)$ and full quality of reciprocal interconnection $\left(\theta_{ij} = \theta_{ji} = 1\right)$ are imposed.

Under this regime firms' profits only depend on prices and quality and we have a two stage game with perfect information. A regulatory policy as in Definition 1 implies that monetary flows balance and that transits on firms' network have all the same marginal cost. This regulatory policy requires a big amount of information on firms' costs, activities and technology and it seems consistent with observed interventions in these kind of markets frequently oriented to reciprocity in interconnection conditions[14].

In the second stage of the game, firms' decision problem (for $n=i,j$) is

[14] For example 1995 Oftel's consultative document or US Telecommunication Act (1996) underline the importance of reciprocal access pricing.

$$\max_{p_{ni}} \Pi_n\left(p_n; p_{-n}; \boldsymbol{a}_n; \boldsymbol{a}_{-n}\right) \qquad (7)$$
$$s.t.\ \ t_n = t,\ \ q_{n-n} = 1,\ \ g_n = g$$

where $\boldsymbol{a}_n$ and $\boldsymbol{a}_{-n}$ are firms' first stage optimal choices about quality.

Now, we can prove the following

Proposition 1: Under GCR network firms will choose the maximum level of vertical product differentiation and in equilibrium both firms earn positive profits.

Proof:

Solving (7), given A1 and A2, it's possible to get firms' reaction functions in the second stage of the game. They are respectively for firm *i* and *j*:

$$p_i = \frac{p_j + cg - \underline{\Psi}}{2}$$
$$p_j = \frac{p_i + cg + \overline{\Psi}}{2} \qquad (8)$$

Thus, equilibrium prices in a Bertrand-Nash equilibrium are $\left(p_i^*; p_j^*\right) = \left(cg + \frac{\left(\overline{\boldsymbol{d}} - 2\underline{\boldsymbol{d}}\right)}{3}\Delta\boldsymbol{a}\ ; cg + \frac{\left(2\overline{\boldsymbol{d}} - \underline{\boldsymbol{d}}\right)}{3}\Delta\boldsymbol{a}\right)$. Substituting (8) into (5), it is immediate to check that demands in equilibrium are equal to $D_i^* = \frac{\overline{\boldsymbol{d}} - 2\underline{\boldsymbol{d}}}{3}\ ; D_j^* = \frac{2\overline{\boldsymbol{d}} - \underline{\boldsymbol{d}}}{3}$ exactly as in Tirole (1988). The equilibrium price vector corresponds to firms' optimal second stage choice, then, going backward to the first stage where decisions on quality are taken, each firm (*n=i,j)* will face the following problem:

$$\max_{a_n \in \left[\underline{a}; \overline{a}\right]} \Pi_n\left(p_n^*; p_{-n}^*; \boldsymbol{a}_n; \boldsymbol{a}_{-n}\right)$$

More precisely, each firm can choose the optimal level of quality[15] in order to maximise the following expressions:

[15] We are assuming the existence of a maximum and a minimum level of quality the former allowed by contemporary technologies, the latter imposed by market regulatory standards.

$$\Pi_i = \left[\frac{\bar{d}-2\underline{d}}{3}\left(a_j - a_i\right) - (1-g)(c-t)\right]\left(\frac{\bar{d}-2\underline{d}}{3}\right) + (t-c)(1-g)\left(\frac{2\bar{d}-\underline{d}}{3}\right)$$
$$\Pi_j = \left[\frac{2\bar{d}-\underline{d}}{3}\left(a_j - a_i\right) - (1-g)(c-t)\right]\left(\frac{2\bar{d}-\underline{d}}{3}\right) + (t-c)(1-g)\left(\frac{\bar{d}-2\underline{d}}{3}\right) \quad (9)$$

As we can notice, firm *i* will set the smaller amount of quality independently by rival's choice and firm *j* will behave the other way around selecting the maximum amount of quality into quality domain, that is

$$\frac{\P\,\Pi_i}{\P\, a_i} < 0$$
$$\frac{\P\,\Pi_j}{\P\, a_j} > 0$$

Hence, in a subgame perfect equilibrium, the optimal level of qualities for services are $\left(a_i^*; a_j^*\right) = \left(\underline{a}\ ; \bar{a}\right)$ and the maximum level of vertical differentiation between firms' services is achieved. By substitution it is immediate to check that equilibrium profits are positive for both networks.

Formally, looking at the proof of Proposition 1, we can notice a peculiar feature of the model: each firm'profit depends linearly upon the quality of services. Competitors want to set a boundary level of quality and they would increase even more product differentiation if it was possible. An equilibrium is reached because services' quality is defined on a closed interval and firms will set upper and lower boundaries of such an interval; in other words, a local maximum of profit functions, supposed continuous, coincide with one quality domain's extreme.

Intuitively, exactly as in Shaked and Sutton (1982), vertical product differentiation is used as a tool for reducing price competition. Two kinds of services are sold in the market: low quality services, in terms of connection and bandwidth, at a low price and high quality, more expensive ones. Network firms provides services to different consumers (*light and heavy users*) at different prices both earning positive profits[16]. In the case of a global connectivity regulation, firms neither can manipulate reciprocal access charges, nor they can distort quality of reciprocal interconnection in order to get competitive gains on rivals. Hence, vertical product differentiation is the unique legal instrument to decrease market competitiveness, increasing profits.

[16] This is, for instance, perfectly consistent with business practices of Internet backbones analysed by Crémer and Hariton (1999).

Nevertheless, a GCR simply imposes reciprocal access prices without determine their values, which are fixed by network firms. As noticed by Laffont, Rey and Tirole (1998) and Armstrong (1998) in a framework in which operators must charge subscribers the same charge for services delivered on or off net, access tariff could be used as a tool of tacit collusion on retail prices and it may facilitate joint profit maximisation. In our model, collusion on access tariffs will be the unique way in which a network firm may get positive profits if vertical product differentiation is not allowed and it decides to manage rival's off net services. With no product differentiation and networks interconnection, firms compete on prices undercutting rival's retail tariffs; this will increase services' demand inducing losses for each unit of managed traffic. Networks will react colluding on access charges. More formally:

Proposition 2: Under a GCR, whereas vertical differentiation is not allowed, firms may decide to manage only on-net services or to be interconnected colluding on access charges.

Proof:

With no vertical product differentiation $\left(\Delta a = 0\right)$ equilibrium prices are $p_i^* = p_j^* = g\ c \leq c$ and equilibrium profits, for *n =i,j,* are given by

$$\Pi_n = \frac{(1-g)\left(\overline{d} - \underline{d}\right)(3t-c)}{3} \qquad (10)$$

In order to gain non negative profits networks can manage only on-net services $\left(g = 1\right)$ earning zero profits (in this case p=c and we reach a Bertrand-Nash Equilibrium) or alternatively reciprocally interconnect (γ<1). In the latter case, retail prices are lower than marginal costs hence each firm get selling losses. In order to compensate them, firms will increase *t* adove *d=c* gaining higher access profits since (XXXX). Furthermore, for a given collusive access price t', profits increase reducing on-net services XXXX.

Finally, we may notice as a particularly tight regulation (reciprocal access prices, full quality of interconnection, no products differentiation), combined with a severe prohibition of collusion on access tariffs, involves a perverse outcome: each firm becomes a on-net service specialised provider breaking connections with possible competitors.

5. Connectivity, Quality and Price Competition in Network Industries under ECP Regulation

In the previous section, we have seen that network firms, under a regulatory policy which impose full interconnection, will differentiate their products in order to weaken price competition on retail services. Nevertheless, on the one hand, a GCR can be really difficult to impose, on the other it requires a large amount of information to be implemented (on demands, costs and network traffic...). Then, it can be meaningful to compare that kind of regulatory policy with a weaker form of regulation which can be reasonably easy to impose with a small amount of information (basically only on reported costs).

Whereas a regulator only has information on firms' costs (marginal cost of production and opportunity cost of access) a commonly used rule for determining access tariffs is the Efficient Component Pricing Rule (ECPR) (Baumol (1983), Willig (1979)). We define, in our framework, a regulatory regime inspired to this rule as:

Definition 2: An *Efficient Component Pricing Regulation (ECPRe)* is a regulatory policy which simply impose a ECPR on reciprocal access prices. In particular access charges are set for *n=i,j* as:

$$t_n = \theta_{n-n} c + \beta \qquad (11)$$

where β is the symmetric opportunity cost of access.

Under an ECPRe both firms can compete effectively not only on price and quality, but also on reciprocal quality of interconnection. In this case we have cost-based access charges which depend on this quality level chosen by any network firm. For the sake of tractability we will introduce, without loss of generality, a symmetric installed base equal to $\overline{q}$. Logically, we shall have a three stage game where in the first stage firms compete on quality of interconnection, secondly on the quality of services and finally on retail prices. The unique constraint they face is given by the rule (11).

As in the previous section, we can compute the Nash equilibrium in prices and, by backward induction, we can analyse firms' optimal choices in terms of services' quality given what was chosen in the third stage of the game. As it is possible to show, a firm’s demand increases with respect to its installed base, giving account of the role of network externalities; nevertheless, under an ECPRe where quality of interconnection can be manipulated in the first stage, vertical product differentiation seems to disappear and an imitative convergence to the maximum (into the restricted domain) level of services’quality characterises firms’behaviour. More precisely:

Proposition 3: Under an ECPRe, both network firms will choose the maximum level of services quality (no vertical product differentiation).

Proof:

See Appendix 1.

Let's do the final step. In the first stage of the game both players compete on interconnection quality θ taking into account an ECP rule imposed by a regulator.

Taking into account previous stages' outcomes we obtain that network firms will set a symmetric level of interconnection quality in a SPE: the best reply dynamics leads both firms to a global degradation of connectivity. The following proposition summaries this result:

Proposition 4: Under an ECPRe, a global degradation of interconnection quality is a subgame perfect equilibrium.

Proof:

See Appendix 2.

Then, the effects of an ECPRe are a maximum level of services quality selected by both networks and a global degradation on connectivity. Firms will not use, as usual, product differentiation to lower price competition but they will prefer to implement a very bad level of reciprocal interconnection. Thus, a precise business strategy phases out: to sell high quality services to unattached consumers which, once attached, will have some difficulties to use other firm's services given a bad reciprocal connectivity between networks. In this case it is interesting to notice the following:

Corollary 1: Under an ECPRe in a subgame perfect equilibrium a Bertrand Equilibrium is reached by network firms.

Proof:

It is sufficient to substitute results of propositions 3 and 4 in expression (A1) to get a level of price in the subgame perfect equilibrium equal to *c*. □

The two analysed regulatory regimes imply two deeply different results in terms of quality and connectivity: in the next section, as concluding remarks, we will compare these outcomes.

6. Concluding Remarks

In this paper we have analysed possible effects of different regulatory regimes on competition between network firms (i.e. internet providers, mobile telephone companies etc.). We have compared two regulatory policies, one particularly heavy (*Global Connectivity Regulation)* aimed to impose a high degree of interconnection quality between firms, and one softer (*Efficient Component Pricing Regulation)* which sets simply a ECPR on access tariffs.

Under a GCR firms cannot manipulate interconnection quality and access charges so, quite traditionally, they will vertically differentiate their products in order to reduce price competition on final services. A firm will produce high quality services and the other low quality ones; both of them will get positive profits.

On the other hand, under a ECPR, networks are able to set any level of interconnection quality; in this regulatory framework both firms will produce high quality services, implementing a global degradation of reciprocal connectivity. Each firm will sell high quality services on its network giving bad access to its rival and hence reducing off-net services'quality. Both firms will strongly compete on prices reaching a Bertrand equilibrium in the last stage of the game, thus sharing market demand.

Finally, from a regulatory perspective, a taught regulation of connectivity implies vertical products differentiation, an high level of interconnection quality and a relevant segmentation of market demand. In opposition, a lighter regulation involves no vertical products differentiation (but convergence to high quality services) but a more competitive outcome in retail prices. Thus, a regulator seems to face, in designing a regulatory regime for network industries, a relevant *trade-off* between global connectivity and market's competitiveness.

Baake and Boom (2001) have recently argued that quality differentiation does not only reduce price competition but also encourage the co-ordination for the achievement of compatibility between firms in industries with network externalities. In our set up, a linkage induced by regulation arises between quality differentiation and price competition: network firms will chose product differentiation if they cannot decrease quality of reciprocal interconnection; whereas a global degradation of connectivity is allowed by the regulator, networks will choose to share market demand in a Bertrand-Nash equilibrium.

Appendix 1

Proof of Proposition 3:

The proof is basically equivalent to the proof of Proposition 1 except for the constraints imposed by regulation. If we maximise, with respect to prices, expressions (6) under A1, A2 and a balanced flows condition, we get a Bertrand-Nash equilibrium given by:

$$
\begin{aligned}
p_i &= c + \frac{\left(\overline{f} - 2\underline{f}\right) j}{3} - \frac{(1-g)}{3}\left[t_j - t_i + 2d_i + d_j\right] \\
p_j &= c + \frac{\left(2\overline{f} - \underline{f}\right) j}{3} - \frac{(1-g)}{3}\left[t_i - t_j + 2d_j + d_i\right]
\end{aligned}
\qquad \text{(A1)}
$$

with $j = \overline{q}\left(q_{ji} - q_{ij}\right)$. Substituting (A1) into demand functions, we obtain firms' demand at the end of the third stage:

$$
\begin{aligned}
D_i^* &= \left(\frac{\overline{f} - 2\underline{f}}{3}\right) - \frac{(1-g)}{3j}\left[2\left(t_i - t_j\right) - d_i + d_j\right] \\
D_j^* &= \left(\frac{2\overline{f} - \underline{f}}{3}\right) - \frac{(1-g)}{3j}\left[2\left(t_j - t_i\right) - d_j + d_i\right]
\end{aligned}
\qquad \text{(A2)}
$$

As it is easy to check, these demands are increasing with respect to the installed base and rival's costs while they decrease when firm's costs increase. Using (A1) and (A2) into (6) we can obtain second stage profits which are maximised by both firms for services' quality $\left(a_n\right)$ taking into account constraint (11). From first order conditions, putting

$$
\Delta q = \begin{cases} \left(q_{ij} - q_{ji}\right) & if\ q_{ij} > q_{ji} \\ \left(q_{ji} - q_{ij}\right) & otherwise \end{cases}
\qquad \text{(A3)}
$$

we obtain firms'reaction function in terms of quality of services given by:

$$\boldsymbol{a}_i = \boldsymbol{a}_j + \boldsymbol{j} + \frac{(1-g)c(1+6\boldsymbol{b}c\Delta\boldsymbol{q})^{\frac{1}{2}}}{3}$$
$$\boldsymbol{a}_j = \boldsymbol{a}_i + \boldsymbol{j} + \frac{(1-g)c(1+6\boldsymbol{b}c\Delta\boldsymbol{q})^{\frac{1}{2}}}{3} \qquad \text{(A4)}$$

As it is immediate to verify, functions in (A4) have no intersection into the domain $\left[\underline{\boldsymbol{a}};\overline{\boldsymbol{a}}\right]$ since they are parallel lines. These two lines are not overlapped since it is always true that

$$2\frac{(1-g)c(1+6\boldsymbol{b}c\Delta\boldsymbol{q})^{\frac{1}{2}}}{3} > 0 \qquad \text{(A5)}$$

Thus, firm *j*’s reaction line is always above to firm *i*’s one. Both reaction functions are continuous and differentiable on our domain and they will be constant functions in correspondence of domain’s extremes. As shown in figure 2, in correspondence of a certain quality level selected by any firm we will have a best reply dynamics which suggests a continuos increase in quality levels.

(INSERT FIG. 1)

Hence, for each network firm is convenient to increase product quality given any quality level fixed by its rival. Using Weierstrass’s theorem, we can claim for a local maximum of profit functions at the upper bound of our interval. Then, we have that in the second stage of the game a Nash equilibrium exists and it is given by:

$$\exists! \left(\boldsymbol{a}_i';\boldsymbol{a}_j'\right) = \left(\overline{\boldsymbol{a}};\overline{\boldsymbol{a}}\right) \text{ where } \overline{\boldsymbol{a}} = \underset{a_n \in \left[\underline{a};\overline{a}\right]}{\arg\max}\, \Pi_n\left(\boldsymbol{a}_n;\boldsymbol{a}_{-n}\right) \text{ for } \forall n$$

Firms do not differentiate their services and they select the maximum level of quality.

Appendix 2

Proof of Proposition 4:

Substituting (10) and $\left(a_i';a_j'\right)=\left(\overline{a};\overline{a}\right)$ into (6), and maintaining previous assumptions, we get first stage profits which now depend only on interconnection quality. Hence, each firm maximises its profits with respect to q_{n-n} . From first order conditions we obtain, with some calculations, firms' reaction functions given by:

$$
\begin{aligned}
q_{ij} &= q_{ji} - \frac{\left(1-\underline{f}\right)^2 \overline{q}^2 + 4\left(1-g\right)^2 b\overline{q}}{3\left(1-g\right)^2 c^2 \overline{q}} \\
q_{ji} &= q_{ij} - \frac{\left(2-\underline{f}\right)^2 \overline{q}^2 + 4\left(1-g\right)^2 b\overline{q}}{3\left(1-g\right)^2 c^2 \overline{q}}
\end{aligned}
\qquad \text{(A6)}
$$

As in Appendix 1, expressions (A6) are parallel lines and firm *i*'s reaction line is always above of firm *j*'s one as it is easy to check using (A6). As above, some constant parts of reaction functions arise given that even here we are working with a restricted domain. Best reply dynamics states that whereas a network sets a certain level of interconnection quality its rival will react choosing a lower level of q. This process will continue until the lower bound of the domain of q is reached (see figure 2):

(INSERT FIGURE 2)

Thus a subgame perfect equilibrium will be given by

$$\exists! \left(q_{ij}';q_{ji}'\right)=\left(0;0\right)$$

Then, both networks will choose global degradation of connectivity.

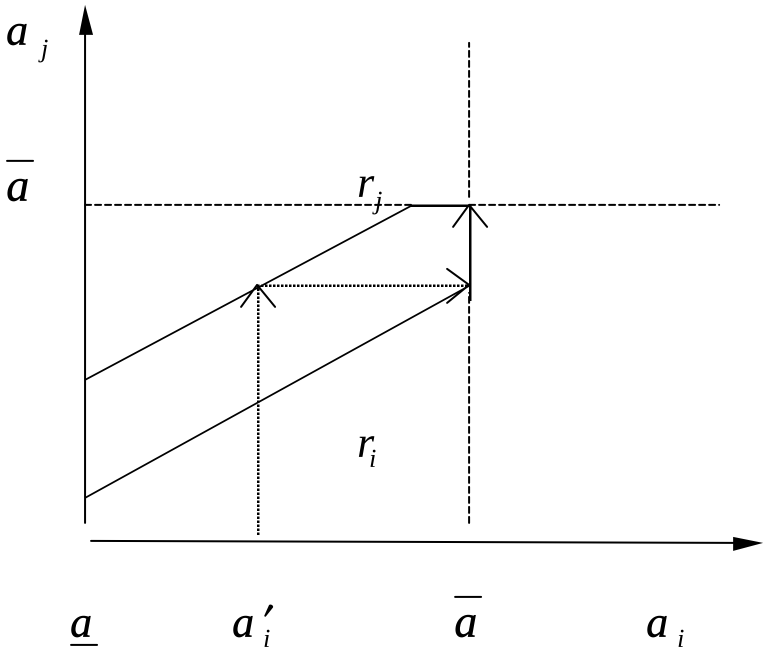

FIGURE 1

Second Stage Best Reply Dynamics

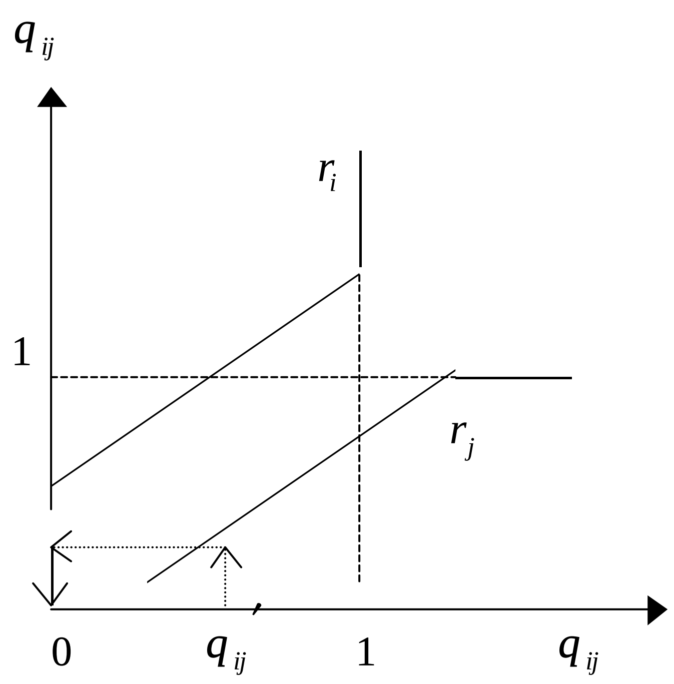

FIGURE 2

First Stage Best Reply Dynamics

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