# SERVICE PROVISION ON A NETWORK WITH ENDOGENOUS CONSUMPTION CAPACITY*

**Nikolaos Georgantzís and Carlos Gutiérrez-Hita****

WP-AD 2008-01

Corresponding author: N. Georgantzís: LEE/LINEEX and Economics Dept., Universitat Jaume I, Castellón, Spain. E-mail: georgant@uji.es

Editor: Instituto Valenciano de Investigaciones Económicas, S.A.
Primera Edición Marzo 2008
Depósito Legal: V-1499-2008



* Financial support by the Instituto Valenciano de Investigaciones Económicas through one of its research grants and the Spanish Ministry of Education and Science (SEJ 2005 07544/ECON) is gratefully acknowledged. All errors are the authors responsibility alone.
** N. Georgantzís: Universitat Jaume I; C. Gutiérrez-Hita: Universidad Miguel Hernández. E-mail: cgutierrez@umh.es.

# SERVICE PROVISION ON A NETWORK WITH ENDOGENOUS CONSUMPTION CAPACITY

**Nikolaos Georgantzís and Carlos Gutiérrez-Hita**

## ABSTRACT

We present a model in which the consumers' capacity to access a service provided on a network depends negatively on the price charged by the network owner per capacity unit. Several scenarios concerning the structure of the downstream service provision market are studied. First, a monopolist operates in both the network and the service provision stage. Second, we assume duopolistic competition between the network owner and the entrant. Third, we allow for endogenous differentiation of the services provided by the two competitors. Generally speaking, the duopolistic structure does not necessarily enhance consumer surplus. Furthermore, competition in the service provision market may reduce social welfare, either due to excessive differentiation or due to a low network density.

**Keywords:** telecommunications markets, regulation, endogenous consumption capacity

**JEL classification:** D43, L13, L51

# 1 Introduction

The main reasons to regulate telecommunications relate to the special characteristics of the supply and demand structures and the overall market organization. The telecommunications sector is capital intensive, characterized by large sunk investments necessary to set up a network. Historically, service production in the telecommunications sector has been undertaken by a network operator, who has been also acting as a monopolist in the service provision market. In this case, the role of regulation has been to ensure that the monopolist behaves in accordance with the public interest, avoiding possible abuses of monopoly power. The main economic argument for this kind of intervention was that a single operator would be able to provide services at lower rates and with a wider coverage than a market served by a number of smaller scale competitive operators. In fact, a single operator is in a better position to dimension and plan the construction of a network (technical efficiency) and to avoid unnecessary investments and excess capacity. Thereby economies of scale can better ensure compatibility of all parts of the network, and technical and administrative cost related to network integration and interconnection can be minimized.

However, this institutional set up has proved to be rather inefficient in accommodating the sharp demand increases within a wave of liberalization and privatization processes. On one hand, monopolists have been unable to cover customer demand in a satisfactory way. As a consequence, it has been very difficult both to control tariffs and to ensure high productivity. On the other hand, the pressure to allow new operators into the market has increased, mostly in the presence of rapid technological advances and development of new products as broadband internet access. Depending on the measures adopted, three general types of market may emerge. First, in order to encourage efficiency, a number of countries have opted for unbundling network property and service provision. Second, some countries have liberalized the service provision market maintaining the monopoly in the ownership of the network. Finally, in many cases, the network monopolist is allowed to compete at the service provision market.

However, in order to assess the desirability of a given market structure, the social gains from increased competition must be compared to possible efficiency losses associated with service provision by many smaller-scale providers. Indeed, the comparison between the advantages and disadvantages of competition is not a trivial task, although there seems to be a general consensus in favor of competition. Free and open competition benefits individual consumers by ensuring lower prices, new and better products and services than occurs under monopoly conditions. In a competitive market firms compete for customers by lowering prices and increasing the wealth of the society. A policy framework to establish, foster, and regulate competition is critical to the delivery of benefits expected and demanded by consumers. Then, in order to achieve the benefits of competition described above, governments and regulators must establish an appropriate policy framework to govern the telecommunications sector.

Once it becomes clear that a more competitive environment should be pursued, the problem arises that in a sector like the one described above achieving perfect competition is difficult if not impossible, because in most areas there is typically only one supplier. Therefore, when perfect competition is far from feasible and the market forces cannot automatically lead to the first best solution through free entry, the regulator is faced with the question of which kind of competitive structure would be the most reliable in each specific case. Most often, the point of departure in national telecommunication markets is one incumbent operator which provides the network jointly with the service. It is possible that other network suppliers will arrive at the market as long as tariffs are high enough to allow them recover their entry costs. In the related literature, this case is referred to as two-way access or interconnection model. However, it may be very difficult for new suppliers to enter into the market due to institutional or technical barriers to entry. The latter may include economies of scale and economies of scope. Furthermore, economies of vertical integration beyond the network are usually large in telecommunication markets. An example of this can be found in one-way access cases.[1]

In many such industries, a consumer's connection to the network depends, at least partially on the network owner's decision concerning the density network available, which in its turn determines the customer's capacity to consume the services available. In some other cases, consumers decide their own consumption capacities. For instance, electricity networks are accessed by households through nodes providing access to local grids. The capacity installed is determined by the magnitude of the investment undertaken by the consumer. Thereafter, the consumer's demand of the services provided through the electric network critically depends on his private investment decision. At the same time, this decision depends on the cost borne by the consumer per unit-capacity installed, which is determined by an access price charged by the network owner per capacity unit. Alternatively, the network owner may decides the capacity available at each price, which is usually the case with telecommunications markets when broadband internet access is offered to the user through a DSL (Digital Subscriber Line) technology. Depending on the cost of different connection alternatives, users may install a superior Internet connection enhancing the speed with which they can access Internet services (perform searches, download pages, exchange files, etc.), thus determining their potential demand of these services within the time they can spend online. To highlight the importance of the issues studied in the present paper, we mention a recent case of regulation, in which the Spanish Commission for the Market of Telecommunications (CMT) reduced the price paid by new broadband service providers to the incumbent of the network, *Telefonica*. The measure was adopted as a means of promoting competition

[1] For a detailed revision of one- and two-way access and the pricing rules used in telecommunications markets see Vogelsang 2003.

in the provision of broadband Internet services by guaranteeing fair entry conditions to new entrants wishing to use *Telefonica*'s loop for Internet allowing a provider's broadband services to reach the user.

In the telecommunications case described above, the resulting pricing scheme is slightly different from standard two-part tariffs, in that, prior to competition in the final service market, the fixed access fee or lease price paid to gain access to the grid determines the potential density of demand or, in other words, the market size. This is a central feature of our analysis. A further element we want to capture is the fact that, usually, the capacity provision market is less competitive than the service provision one. As we mentioned above, this may be due to a number of reasons, among which the most important are the institutional history of many strategic markets (energy, telecommunications, etc.) and the size of sunk costs necessary to setup the network infrastructure.

The literature on markets served by a network has paid special attention to the suppliers' ability of applying nonlinear pricing schemes. Regarding two-way access it is interesting that such schemes are based on two-part tariffs consisting of a fixed component granting access to the network and a variable one, linearly depending on the units of service consumed. Recently, the issues of partial consumer participation in a network and the effects of interconnection pricing have separately attracted some economists' attention. Specifically, with respect to the first of these issues, Dessein (2003) and Schiff (2002) develop models with partial consumer participation. However, in their framework consumer participation depends on whether the consumer's reservation price exceeds the generalized price, defined as the sum of the fixed access price and the variable expenditure due to consumption of the final service. This modeling strategy is analogous to that adopted by Peitz (2005a and 2005b) in a spatial model with elastic demand in that both methods yield endogenously determined demands following the generalized prices and, thus, market competition. In fact, Peitz also deals with the issue of interconnection, suggesting an asymmetric regulation of access pricing. However, in those papers, a two-part tariff is used by firms possessing independent networks. The regulator establishes an asymmetric access price policy such that the entrant pays a lower access to the incumbent for the use of the network. This has two positive effects on competition: the entrant is more likely to enter and, if this occurs, competition is enhanced. This measure protects consumers but decreases total surplus because it distorts the per-minute price of the incumbent. In an earlier paper by Armstrong (1998), a fixed retail price was assumed to be charged by an incumbent serving a population of consumers with a unit demand for the service. A higher access price leads the entrant to set lower retail prices. Behringer (2004) studies a duopoly model in which there are two interconnected networks across which access prices are determined non-reciprocally by each network's owners. Like in many of the aforementioned papers, demand is elastic. In these frameworks, entry into the telecommunications industry will increase total welfare compared with the initial monopoly situation, depending on the utility gains from connection and from outgoing calls. Contrary to these approaches, we deal with the case of one-way access. In our framework there is a unique network owned by the incumbent, on which the demand potential is determined by the cost borne by consumers at the capacity installation stage, preceding both the entry of the network owner's competitor and posterior price competition. In a somehow related but differently focused paper by Aguilar and Herguera (2004) a model is proposed to study the effects of interconnection between telecommunication networks whose capacity is fixed by the regulator. It is shown that a capacity-based regime induces more aggressive pricing in the final service, increasing welfare. De Bijl and Peitz (2002, 2005, 2006) analyze local loop unbundling in which the entrant needs to connect to the network and it has market power. They stress that access regulation is appropriate in early stages of competition, when entrants have not yet developed alternative infrastructures. However, they found that unbundling requirements are neutral to competition.

We set up a model of spatial competition in the provision of the final service. Consumer heterogeneity captures the consumers' differing degrees of specificity to one of the services available in the market. Suppliers' locations represent the choice of service characteristics. In a stage preceding the usual location and pricing stages, the network owner determines the consumer's consumption capacity, represented by consumer density along the service characteristics space. Finally, the entrant's connection cost is determined by either the network owner or a regulator. Under this environment, we study *i*) the relation between service competition and network access pricing with endogenous consumption capacity, *ii*) the efficiency of the resulting market depending on the overall capacities and market split among the providers of the final service and *iii*) the degree of differentiation between service providers in comparison to the socially optimal one.

The rest of paper is structured as follows. Section 2 presents the set up of the model and the benchmark case. Section 3 develops and solves the model under different scenarios concerning the industry configuration. Section 4 discusses the welfare implications of our framework. Section 5 presents the main conclusions and policy implications. All proofs are included in an appendix at the end of the paper.

## 2 The theoretical benchmark

A firm labelled $M$ is the owner of the network infrastructure which is necessary in order to provide a service to a fixed population of users (broadband internet access, for instance). Consumer heterogeneity is represented in the way adopted by the spatial model of Hotelling (1929) and its extensions introduced by D'Aspremont et al. (1979), where consumers' ideal varieties are uniformly distributed along the unit interval with a constant density, $D$. Let $D$ also represent the market potential resulting from a consumer's consumption capacity decision. This depends on the quality of the network access. In the case of broadband internet access its means the capacity of the connection. Let the consumer's installed consumption capacity $D$ inversely depend on a price $p$ charged by the network owner, as implied by $D = 1 - p$. The intuition behind this is that, for a given exogenous capacity installed, the network owner decides the density offered depending on the consumers' demand for capacity. The capacity available to the users is offered at a constant unit cost, $k \in [0, 1)$.

## 2.1 Monopoly

As a benchmark case, we first consider that $M$ is the monopolist in the provision of the service to consumers, incurring a constant marginal cost $c_M$. In all the scenarios considered hereafter, we assume that service suppliers are obliged to provide universal service, although this in our framework does not imply a constant market size, which is ultimately determined by consumption capacity decisions. After having charged a price $p$ for the consumption capacity installed, $M$ sets a retail price $r_M$ per unit of service consumed. Although this pricing pattern is very similar to a standard two-part tariff, it corresponds to a two-stage decision, of which the first part determines the market potential and the second extracts surplus from a fixed population of consumers.

Given $r_M$, $p$ and the resulting network density $D$, each consumer is assumed to have a unit demand for the service which yields her a utility of $U = max\{R - p - r_M - t \cdot (l_M - x)^2, 0\}$, where $R$ is a reservation price for the service, $l_M$ is the monopolist's variety on the line of real numbers representing the product characteristics space, $x$ is the user's ideal variety on the interval $[0, 1]$ and $t \cdot (l_M - x)^2$ is a term capturing the quadratic utility loss experienced by the user due to the distance between his ideal variety and that actually provided to her by $M$. Notice that the utility enjoyed from the consumption of a unit service depends indirectly on the capacity installed as a function of $p$. Moreover, the capacity installed determines the density of services used per consumer.

Using the complete market coverage restriction, the monopolist's profit is given by:

$$\pi_M = D \left( \underbrace{(p - k)}_{\substack{Network \\ markup}} + \underbrace{(r_M - c_M)}_{\substack{Service \\ markup}} \right). \tag{1}$$

Then, it is straightforward to show the following result:

**Proposition 1 (Monopoly outcome):** *A network monopolist $M$ operating under the restriction of global service provision locates in the middle of the segment ($\widehat{l}_M = 1/2$), charging an access price of $\widehat{p}_M = 0$ yielding maximal density $\widehat{D} = 1$ and a retail price for the provision of the service equal to $\widehat{r}_M = R - t/4$.*

Proposition 1 implies that a monopolist extracts the maximum possible surplus, after having induced maximal consumption density (setting the capacity access price equal to zero) and a minimal distance from the consumers located on the extremes of the $[0, 1]$ interval.

Substituting the equilibrium magnitudes presented in Proposition 1 into the monopolist's profit function we get:

$$\widehat{\pi}_M = R - k - c_M - \frac{t}{4}.$$

Therefore, as expected, the monopolist's equilibrium profits positively depend on the consumer's maximal willingness to pay for the service, and negatively on the unit costs of service and capacity access provision, as well as the heterogeneity coefficient $t$. Intuitively, the two cost parameters $k$ and $c_M$ have a greater impact on the monopolist's maximal profit than the heterogeneity of consumers measured by $t$, because all demand is automatically captured by $M$.

The solution coincides with the implementation of the socially optimal monopoly location and access capacity pricing scheme, as it maximizes the market potential. However, this should not be taken to imply that this is the best solution for the consumer, given that the transfer of $r_M$ from the consumer to the network monopolist is not taken into account. It is a trivial consequence of our framework, that infinite pricing schemes exist involving different levels of consumer surplus, all of which would lead to the same level of aggregate welfare. In fact, there is a trade-off between the monopolist's profitability from the access capacity market and consumer surplus. More specifically, when $r_M = c_M + k$ the monopolist's profit is minimized with $\pi_M = 0$ and maximal consumer surplus. This implies the aforementioned continuum of regulation schemes yielding maximal total social welfare, depending on the regulator's decision on the implemented $r_M \in [c_M + k, R - t/4]$.

# 3 Duopoly in service provision

We now extend the notation introduced so far to setup a model in which a new entrant, $E$, competes in prices with $M$ in the provision of the service, faced with a unit cost $c_E$. Apart from variable costs related to the provision of the service, the entrant has to pay the network owner a connection fee $\alpha \in [0, 1]$ per unit of service. In this sense, our framework is one of one-way access where the entrant needs to connect to the network in order to supply the service. Depending on the scenario considered, this fee may be set by the regulator or the network owner. Therefore, apart from the usual business-stealing effect, the entrant's market share has also a positive effect on the network owner's profits, as the latter earns $\alpha$ per service unit provided by $E$. From the definition of $\alpha$, we do not rule out the possibility of $\alpha \leq k$. Thus, the cost $k$ borne by $M$ may not be fully covered by the entrant's connection fee or may be just equal to it. Although this would not be what one would expect from the monopolist's decision on $\alpha$, it could correspond to the regulator's decision to subsidize the entrant or partially compensate $M$ for the costs incurred to maintain the network infrastructure. Finally, depending on the case considered, we allow $E$ and $M$ to simultaneously chose locations on the line of real numbers representing the product characteristics space. In order to isolate the effects of entry fee and location choices on the resulting subgame perfect Nash equilibria (SPNE), we consider 4 cases:

- **Case 1:** Exogenous connection fee and firm locations,
- **Case 2:** Exogenous connection fee and endogenous firm locations,
- **Case 3:** Endogenous connection fee and exogenous firm locations,
- **Case 4:** Endogenous connection fee and firm locations.

In the firm location stage, $M$ is always the firm on the left and $E$ is the firm on the right. In the case of exogenous firm locations, we assume that the two firms provide services which correspond to the extremes of the segment $[0, 1]$ along which consumers' ideal varieties are distributed. When the entrant's connection fee is exogenously given by the regulator authorities, we consider $\alpha$ as a model parameter. Superscripts 1-4 denote equilibrium magnitudes corresponding to each one of the four cases.

### 3.1 Case 1: Exogenous connection fee and firm locations

The two firms compete in prices taking each other's location on the extreme of the $[0, 1]$ interval as given. The entrant's connection fee $\alpha$ paid to $M$ is also exogenously given. Thus, the resulting game consists of two stages. First, $M$ sets $p$, which determines the density $D$ or market potential on the network; second, firms simultaneously set retail prices, $r_M$ and $r_E$.

For a given pair of retail prices $r_M$, $r_E$, the indifferent consumer's location is given by:

$$\widetilde{x} = \left(\frac{1}{2} - \frac{r_M - r_E}{2t}\right)$$

yielding service demands $d_M = (1-p)\widetilde{x}$ and $d_E = (1-p)(1-\widetilde{x})$ for the incumbent and the entrant, respectively. Then, the two firms' profits are given by:

$$\pi_M = (p-k)d_M + (p+a-k)d_E + (r_M - c_M)d_M, \tag{2}$$

and

$$\pi_E = (r_E - c_E - a)d_E, \tag{3}$$

respectively.

We solve the game by backward induction. We obtain the equilibrium in the pricing stage first, and substitute the solution into $M$'s profit function to determine the network capacity. The resulting equilibrium yields:

**Proposition 2 (Duopoly with exogenous connection fee and firm locations):** *When the service is provided by a duopoly consisting of the network owner $M$ and an entrant $E$ who is asked to pay an entry cost of $\alpha$ to the former, with both $M$ and $E$ located on the extremes of the unit interval* $[0, 1]$*, an access price of* $p_M^1 = \frac{4(1+k-\alpha)-3t}{12} + \frac{(c_M-c_E)(6t-c_M+c_E)}{36t}$ *is charged to the consumers. Then, Nash equilibrium retail prices are given by* $r_M^1 = \alpha + t + \frac{1}{3}(2c_M + c_E)$ *and* $r_E^1 = \alpha + t + \frac{1}{3}(2c_E + c_M)$*.*

It is interesting to note that the solution described in Proposition 2 accounts for the fact that the network owner's profit is affected less than in the usual spatial competition model by rival's sales, given that the latter pays the former a connection fee of $\alpha$ per unit of service provided to the entrant's clients through the network. The equilibrium in retail prices is symmetric and the effect of the per service unit transfer from $E$ to $M$ has a positive, direct impact on retail prices of both service suppliers.

As a consequence, second stage equilibrium profits are given by:

$$\pi_M(p) = \frac{(1-p)[18t(\alpha+p-k) + 9t^2 - 6t(c_M - c_E) + (c_M - c_E)^2]}{18t},$$

and

$$\pi_E(p) = \frac{(1-p)(c_M - c_E + 3t)^2}{18t},$$

which indicate an interesting property of the framework. Namely, only $M$'s equilibrium profits are (positively) affected by $\alpha$. This can also be seen on equilibrium retail prices which fully reflect increases in $\alpha$. However, for the entrant, this increase in retail prices has no direct effect on equilibrium profits, because it equals the amount the entrant spends per service unit to use the network infrastructure.

By the fixed locations assumption adopted in this case, total transportation costs are equal to those of the monopoly case above. However, a source of inefficiency identified here relates to the network owner's reduced incentives to encourage installation of maximal consumption capacity, because the entrant will now enjoy part of the benefits from a more dense network.

Substituting the equilibrium price $p_M^1$ into expressions (2) and (3) yielding a network density $D < 1$, we obtain equilibrium profits for the incumbent and the entrant firm,

$$\pi_M^1 = \left[\frac{18t(1+\alpha-k) + 9t^2 + 6t(c_E - c_M) + (c_E - c_M)^2}{36t}\right]^2,$$

and

$$\pi_E^1 = \left[\frac{(c_E - c_M + 3t)^2}{18t^2}\right]\sqrt{\pi_M^1},$$

respectively. Note that the entrant's equilibrium profits positively depend on the incumbent's profits. That is,

$$\frac{\partial \pi_E^1}{\partial \pi_M^1} = \left[\frac{(c_E - c_M + 3t)^2}{36t^2}\right]\frac{1}{\sqrt{\pi_M^1}}$$

is always positive for all parameter values, contrary to the property obtained by De Bijl and Peitz (2006) in a symmilar setting. The existence of a network density $D$ promotes that $E$'s profits are not neutral to the access fee $\alpha$ The intuition behind this result is that the higher the participation of $M$ in $E$'s revenues, the less are the former's incentives to undercut prices in order to steal business from the latter.

## 3.2 Case 2: Exogenous connection fee and endogenous firm locations

In this case, the game includes a firm location stage between the stages in which $p$ and retail prices are determined.

The indifferent consumer's location is now given by:

$$\widetilde{x} = \left(\frac{r_E - r_M}{2t(l_E - l_M)} + \frac{(l_E + l_M)}{2}\right).$$

We denote by $l_M$ and $l_E$ firms' location choices on the line of real numbers $(-\infty, +\infty)$. Thus, locations outside the $[0, 1]$ interval may also be chosen. Solution of the game by backward induction leads us to the following result:

**Proposition 3 (Duopoly with endogenous differentiation and exogenous network entry costs):** *When the service is provided by a duopoly consisting of the network owner $M$ and an entrant $E$ who is asked to pay an exogenously determined entry fee $\alpha$ to the former, with both $M$ and $E$ choosing their locations on the interval $(-\infty, +\infty)$, an access price of $p_M^2 = \frac{12(1+k-\alpha)-3t}{8} + \frac{(c_M - c_E)(9t - 2c_M + 2c_E)}{27t}$ is charged to the consumers. Then, the Nash equilibrium locations are $(l_M^2, l_E^2) = (\frac{c_E - c_M}{3t} - \frac{1}{4}, \frac{c_E - c_M}{3t} + \frac{5}{4})$ and the margins for the provision of a service unit by each retailer are given by $r_M^2 = \alpha + \frac{3t}{2} + \frac{2c_E - c_M}{3}$ and $r_E^2 = \alpha + \frac{3t}{2} + \frac{2c_M - c_E}{3}$.*

The most interesting property that is implied in the equilibrium described in Proposition 3 is that both duopolists will locate outside the interval $[0, 1]$, as long as their unit costs of providing the service are not too different from each other in which case one of them might locate inside the segment. In all cases, however, the two firms' locations will not simultaneously deviate from $(-1/4, 5/4)$ towards the center of the unit interval, which would be the necessary condition for a more efficient location than that of the monopolist. Therefore, we find that market competition always yields excessive product differentiation as compared both to the socially optimal and that of the monopolist in the absence of independent entry. Finally, a further inefficiency arising in the case studied here has already been identified in the previous case. That is, the network owner sets an access capacity price above zero, achieving less than maximal market potential.

Substituting the equilibrium magnitudes presented in Proposition 3 into the two firms' profit functions, yields:

$$\pi_M^2 = \left[\frac{108t(1+\alpha-k)+81t^2-72t(c_M-c_E)+16(c_M-c_E)^2}{216t}\right]^2,$$

$$\pi_E^2 = \left[\frac{(4(c_M-c_E)+9t)^2}{108t^2}\right]\sqrt{\pi_M^2}.$$

It can be checked that, like in Case 1, the entrant's profit positively depends on the incumbent's profits as indicated by:

$$\frac{\partial \pi_E^2}{\partial \pi_M^2} = \left[\frac{4(c_E-c_M+9t)^2}{216t^2}\right]\frac{1}{\sqrt{\pi_M^2}}.$$

Comparison between the magnitudes of this effect across Cases 1 and 2 gives:

$$\frac{\partial \pi_E^2}{\partial \pi_M^2} < \frac{\partial \pi_E^1}{\partial \pi_M^1},$$

which implies that the larger degree of differentiation between firms in Case 2 decreases the intensity of strategic interaction, thus, leading to a more moderate effect of the incumbent's profit on those of the entrant. However, it can be checked that the aforementioned difference in the effects of the entrant's profits on those of the incumbent decreases as the difference $c_M - c_E$ increases.

## 3.3 Case 3: Endogenous connection fee and exogenous firm locations

In this case, we assume that the network owner decides on the connection fee $\alpha$ that the entrant is charged per service unit provided to its clients.[2] The decision is made as the same stage at which $p$ is fixed, previous to the retail price competition. Thus, we recover the exogenous location assumption but relax the assumption of network connection fee exogeneity. Profit functions and the remaining notation introduced above are valid here. Solution of the game using backward induction leads us to the following result:

[2] Suppose, for instance, that regulator authorities define the market functioning rules with no further intervention in the market.

**Proposition 4 (Duopoly with endogenous connection fee and exogenous differentiation):** *When the service is provided by a duopoly consisting of the network owner $M$ and an entrant $E$ who is asked to pay a connexion fee $\alpha$ to the former, with both $M$ and $E$ located on the extremes of the unit interval $[0,1]$, $M$ sets $p^3 = 0$, yielding maximal density $D = 1$ and charges $E$ an entry cost of $\alpha^3 = \frac{2(k+1)-t}{2} + \frac{6t(c_M-c_E)-(c_M-c_E)^2}{18t}$. Then, the Nash equilibrium margins for the provision of a service unit by each retailer are given by $r^3_M = c_M + \frac{2(k+1)+t}{2} - \frac{(c_M-c_E)^2}{18t}$ and $r^3_E = \frac{2(k+1)+t}{2} + \frac{6t(2c_M+c_E)-(c_M-c_E)^2}{18t}$.*

From the result reported in Proposition 4, efficiency losses due to less than maximal network capacity induced by a positive $p$ disappear. At the same time, the exogenous imposition of locations on the extremes of the unit interval makes this configuration equally efficient to the monopoly case as far as total transportation costs are concerned. Therefore, this case and the monopoly structure are equally efficient, although it should be noted that the duopoly case studied here improves social welfare through competition yielding lower retail prices.

Substituting the equilibrium magnitudes presented in Proposition 4 into the two firms' profit functions, yields:

$$\pi^3_M = \frac{c_M^2 - c_E^2 + c_M(3 - 2c_E - 6t) + 9t(1 - 2k + t) + c_E(6t - 3)}{18t}, \tag{4}$$

$$\pi^3_E = \frac{(c_M - c_E + 3t)^2}{18t^2}. \tag{5}$$

### 3.4 Case 4: Endogenous connection fee and firm locations

In this case, the two games described above are combined. Firm locations are chosen in a stage following the choice of $\alpha$ and preceding the price competition stage. Notation and expressions introduced above are also valid here. Solution of the game by backward induction yields the following results:

**Proposition 5 (Duopoly with endogenous differentiation and network entry costs):** *When a service is provided by a duopoly consisting of the network owner $M$ and an entrant $E$ who is asked to pay an entry cost of $a$ to the former, with both $M$ and $E$ choosing their locations on the interval $(-\infty, +\infty)$, $M$ sets $p^4 = 0$, yielding maximal density $D = 1$ and charges $E$ an entry cost of $\alpha^4 = \frac{4(k+1)-3t}{4} + \frac{18t(c_M-c_E)-4(c_M-c_E)^2}{27t}$. Then, the Nash equilibrium locations are $(l^4_M, l^4_E) = (\frac{c_E-c_M}{3t} - \frac{1}{4}, \frac{c_E-c_M}{3t} + \frac{5}{4})$ and the margins for the provision of a service unit by each retailer are given by $r^4_M = c_M + \frac{4(k+1)+3t}{4} - \frac{4(c_M-c_E)^2}{27t}$ and $r^4_E = \frac{4(k+1)+3t}{4} + \frac{9t(4c_M-c_E)-4(c_M-c_E)^2}{27t}$.*

Although maximal network density is achieved in this configuration, locations are inefficiently chosen, leading to excessive product differentiation.

Substituting the equilibrium magnitudes presented in Proposition 5 into the two firms' profit functions, yields:

$$\pi_M^4 = 1, \tag{6}$$

$$\pi_E^4 = \frac{(4(c_M - c_E) + 9t)^2}{108t}. \tag{7}$$

With respect to the incumbent's equilibrium profit, it must be noted that if we express profits as a function of costs and connection fee, we get:

$$\pi_M^4 = (1 + \tfrac{3t}{4}) \left[\tfrac{1}{2} + \tfrac{2(c_E - c_M)}{9t}\right] + (\alpha - k) \left[\tfrac{1}{2} - \tfrac{2(c_E - c_M)}{9t}\right]$$

which helps us understand the intuition behind the way $\alpha^4$ is determined. If, for example, $c_E = c_M$ the monopolist sets the connection fee equal to $1+k$ from which the cost of heterogeneity, $\frac{3t}{4}$, is subtracted. If $c_E > c_M$ it can be seen that $\alpha$ is a decreasing function of the cost difference. Intuitively, this can be understood as a strategy aimed at facilitating the entrant's connection and benefitting, through $\alpha$, from a larger number of service units. In other words, the incumbent extracts all possible surplus from the capacity-installing stage, leaving the entrant with some of the benefits from exploitation of consumer heterogeneity through product differentiation. It is also important to observe, that as firms are here free to locate, thus mitigating the fierceness of competition, the resulting retail prices are lower than in the exogenous locations case.

In the following subsection, we discuss the implications of our results for social welfare and economic policy, combining the results presented so far.

# 4 Social welfare considerations

In this framework, social welfare analysis becomes both relatively straightforward and insightful.

Let us recall that the case of monopoly under the assumption of full market coverage case achieves the maximum level of social welfare that can be reached by a single provider of the service. This is given by:

$$SW_M = R - k - c_M - 2\int_0^{1/2} tx^2 = R - k - c_M - \frac{t}{12}.$$

We use this case as a benchmark to assess the effects of liberalization on overall market efficiency.

Using the fact that equilibrium locations will in general be outside the unit interval, in the following specification of social welfare, we consider location pairs for which the incumbent's location lies weakly below 0 and the entrant's location is weakly higher than 1. Then, social welfare in the duopoly case is given by:

$$SW_{Duopoly} = (1-p)(R - k - c_M\widetilde{x} - c_E(1-\widetilde{\widetilde{x}})) - \int_{l_M}^{l_M+\widetilde{x}} tx^2 - \int_{l_E}^{l_E+(1-\widetilde{x})} tx^2.$$

By observation of the above expressions of social welfare, given a specific market structure, there are three sources of possible inefficiencies: first, deviations from the maximal network density $D = 1$ resulting from access capacity prices, $p > 0$; second, higher than minimal transport costs due to location choices different from the pair $(l_M^*, l_E^*) = (1/4, 3/4)$ in the duopoly case, or $l_M = 1/2$ in the presence of a single service provider; third, inefficient splits of the market between the two suppliers. Regarding this last source of inefficiency, consider the case of equal service provision costs, $c_E = c_M$. Then, if firms are symmetrically located with respect to the consumers' unit length segment the efficient market split is one in which consumers are equally shared between the two suppliers. The optimal location of the indifferent consumer is $x^* = 1/2$. With $c_M \neq c_E$, the desirable condition is that the more efficient supplier serves more consumers than the inefficient one up to the point at which the extra traveling paid by clients served along a broader market segment, do not exceed the efficiency gains from being supplied by the efficient provider. Comparison between Duopoly cases 1, 2 on one hand and cases 3 and 4 on the other hand shows that the existence of a connection fee paid by the entrant to the incumbent induces asymmetric splits when there are costs asymmetries between suppliers in the service market. In this framework, this is the major justification for regulating the conditions offered to the entrant in the network connection stage. The interpretation of the remaining sources of inefficiencies is straightforward, but the first of them is not standard in the literature. Thus, several points raised on the efficiency of the structures discussed here are novel and, thus, difficult to compare with other similar results in the literature.

The first observation concerning social welfare refers to the monopoly case. Although we have assumed that the monopolist has the obligation to offer universal service, a non-trivial result states that, under the monopoly scenario, the capacity installed by the consumers will maximize the density of the network, implementing the socially optimal solution. Regarding the service characteristics, the monopolist chooses the central location, which is also the socially optimal solution conditional on the existence of a single provider. As we will see, this location could be improved by a duopolistic service market, as long as firms choose locations which lie sufficiently close to $(1/4, 3/4)$. With respect to this last point, our results indicate that the choice of locations by duopolists in Cases 2 and 4 will in general be more inefficient than the monopolist's location in the middle of the consumers' segment. This is straightforward to show if we have in mind that locating two providers on the extremes of the segment $[0, 1]$ leads to the same total transportation costs as the location of a single provider in the middle of the segment.

Therefore, our results can be seen as a source of pessimism concerning the ability of competition to increase social welfare in markets providing services on a network. On the contrary, the existence of a competitor puts downward pressure on retail prices, although the transfer of revenue from the entrant to the network owner diminishes the latter's incentives to undercut retail prices. Furthermore, this effect persists, although at different levels, no matter who decides on the connection fee. This justifies and supports the alternative measure often adopted by regulators in many countries, in which a fixed transfer is paid to the network owner by the entrant, leaving unaffected the incentives of competitors to engage in pro-competitive retail price undercutting.

The general conclusion drawn from our analysis is that competition may increase the consumer's surplus, but does not necessarily enhance social welfare. Monopoly is as efficient as Duopoly under Case 3, in which differentiation is not allowed beyond the support of consumer preferences. In all other cases, excessive product differentiation is obtained. Cases 1and 2 lead to further efficiency losses due to the incentives provided to the network owner to restrict output in the capacity provision stage.

## 5 Conclusions and policy implications

Our analysis has focused on the fact that a network which is used to provide a service may be accessed by consumers whose connection capacity determines their potential consumption and thus the market size. Although setting the price of access capacity and of the service consumed is very similar to a standard two-part tariff, it corresponds to a two-stage decision, of which the first part determines the market potential and the second extracts consumer surplus.

Apart from this element, our analysis includes other more standard features. First, the network owner participates in the service provision market. At the same time, new entrants are charged a connection fee per service unit they provide to their clients. Finally, the network monopolist and the entrant are assumed to compete in retail prices in the provision of the final service.

Although the literature and regulators have paid some attention to the effects of connection fees and transfers paid by the entrant to the incumbent, our results call for a more cautious attitude towards this issue. Of course, it is important to note that our recommendation for a more permissive attitude towards connection fees charged by the incumbent does not refer to the case in which such fees prevent new firms from entering into the market, as our framework assumes that the structure of the sector is exogenously given. However, once this possibility is ruled out, the entrants' payments in the form of transfers to the incumbent are found to be neutral with respect to the social welfare resulting from each structure, having a negative impact on consumer surplus alone. Therefore, the decision of the

Spanish CMT to regulate *Telefonica*'s network usage prices paid by its rivals can be justified as a measure favoring consumers, rather than overall market efficiency.

Generally speaking, our findings yield far more concerns about market inefficiencies arising from excessive differentiation of services aimed at relaxing price competition rather than satisfying consumers' needs. The importance of product differentiation strategies in markets for services provided on a network is a well documented fact[3], but the possibility of efficiency losses due to excessive differentiation in the endogenous capacity network is a completely novel element of our analysis. Along this line, the main contribution of this paper to the literature on network-based provision of services is that when competition is introduced in the provision of a service, the network monopolist's incentives to encourage final users to install maximal consumption capacity are reduced, leading to a lower than maximal market potential.

# 6 Appendix

## 6.1 Proof of Proposition 1

**Proof.** The monopolist's profit function is $\pi_M(p, r_M) = (1-p)(p-k) + (1-p)(r_M - c_M)$. Behavior at the third stage is defined by the condition:

$$\frac{\partial \pi_M(p, r_M)}{\partial r_M} = 1 - p > 0.$$

This partial derivative with respect to the monopolist's strategy $r_M$ is always positive for all $p \in [0, 1)$. However, following our assumptions, the monopolist cannot fix $r_M$ larger than that guaranteeing full coverage of the market. In fact this restriction determines the monopolist's location. First, the monopolist has no incentive to locate outside the unit interval because consumers are located inside it. Then, $l_M \in [0, 1]$. Provided that the utility for all consumers must be larger or equal to zero, solving for $x$ we get the two roots:

$$x_1 = l_M - \tfrac{\sqrt{R-p-r_M}}{\sqrt{t}}, x_2 = l_M + \tfrac{\sqrt{R-p-r_M}}{\sqrt{t}}.$$

Using these expressions and the fact that the net utility for the consumers located at $x = 0$, and $x = 1$ will be equal to zero due to the monopolists' market power, we get

$$\widehat{x} = 0, \Rightarrow \quad l_M = \tfrac{\sqrt{R-p-r_M}}{\sqrt{t}}; \quad \widehat{x} = 1, \Rightarrow \quad l_M = 1 - \tfrac{\sqrt{R-p-r_M}}{\sqrt{t}}. \tag{8}$$

Then, given that $l_M$ is unique along $[0, 1]$, it is straightforward that $r_M(p) = R - p - \frac{t}{4}$. Now, at the second stage the decision about location is trivial. With $r_M(p)$ substituted in (8), we get that $l_M^* = 1/2$

[3] See the recent study by Greenstein and Mazzeo (2006) on the case of telecommunication markets.

. Finally, at the first stage the monopoly profit function is $\pi_M(p) = (1-p)(p-k)+(1-p)(R-p-\frac{t}{4}-c_M)$, which depends only of the structural parameters and the strategy $p$. The first order condition for an interior solution is

$$\frac{\partial \pi_M}{\partial p} = -R + (k + \frac{t}{4} + c_M).$$

The sign of $\frac{\partial \pi_M}{\partial p}$ determines the value of $p$ and $r_M$. The monopoly profit function can be expressed in a simple way as $\pi_M(p) = (1-p)(R-k-\frac{t}{4}-c_M)$. These two parts of the profit function must be positive to get non-zero profits. Then, $(R-k-\frac{t}{4}-c_M) > 0$, or $-R+(k+\frac{t}{4}+c_M) < 0$; that is, $\frac{\partial \pi_M}{\partial p} < 0$. As a consequence, the best access price for the monopolist is $\widehat{p}_M = 0$, and $\widehat{r}_M(0) = R - \frac{t}{4}$. This completes the proof. ■

## 6.2 Proof of Proposition 2

**Proof.** At the retail stage both firms, $M$ and $E$ set retail prices which in equilibrium satisfy:

$$\frac{\partial \pi_M(r_M,r_E,p)}{\partial r_M} = (1-p)\frac{(a+c_M+r_E-2r_M+t)}{2t} = 0;$$
$$\frac{\partial \pi_E(r_M,r_E,p)}{\partial r_E} = (1-p)\frac{(a+c_E+r_M-2r_E+t)}{2t} = 0,$$

whose simultaneous solution yields $r_M^1 = \alpha+t+\frac{1}{3}(2c_M+c_E)$ and $r_E^1 = \alpha+t+\frac{1}{3}(2c_E+c_M)$. Substituting $r_M^1$ and $r_E^1$ into the profit functions of the incumbent and the entrant we obtain second stage profits,

$$\pi_M(p) = (1-p)\frac{(c_E-c_M)^2+18t(1+\alpha-k)+6t(c_E-c_M)+9t^2}{18t},$$
$$\pi_E(p) = (1-p)\frac{(c_M-c_E+3t)^2}{18t}.$$

Finally, the network monopolist decides $p$ in order to satisfy: $\frac{\partial \pi_M(p)}{\partial p} = (1-p) - \pi_M(p) = 0$, which yields $p_M^1 = \frac{4(1+k-\alpha)-3t}{12} + \frac{(c_M-c_E)(6t-c_M+c_E)}{36t}$. This completes the proof. ■

## 6.3 Proof of Proposition 3

**Proof.** At the 3rd stage firms set retail prices which in equilibrium satisfy:

$$\frac{\partial \pi_M(p,l_M,l_E,r_M,r_E)}{\partial r_M} = (1-p)\left[\frac{\alpha+c_M+r_E-2r_M+t(l_E-l_M)^2}{2t(l_E-l_M)}\right] = 0;$$
$$\frac{\partial \pi_E(p,l_M,l_E,r_M,r_E)}{\partial r_E} = (1-p)\left[\frac{\alpha+c_E+r_M-2r_E-t(l_E-l_M)(l_E+l_M-2)}{2t(l_E-l_M)}\right] = 0,$$

whose simultaneous solution yields retail third stage prices $r_M(l_M,l_E) = \alpha + \frac{2c_M+c_E+t(l_E-l_M)(2+l_E+l_M)}{3}$, and $r_E(l_M,l_E) = \alpha + \frac{2c_E+c_M-t(l_E-l_M)(l_E+l_M-4)}{3}$. Substituting $r_M$ $(l_M,l_E)$ and $r_E(l_M,l_E)$ into the profit functions of the monopolist and the entrant firm respectively, we obtain third stage equilibrium profits,

$$\pi_M(p,l_M,l_E) =$$
$$\left[\frac{(1-p)\left[(c_M-c_E)^2+t(l_E-l_M)(18(\alpha+p-k)-2(c_M-c_E)(2+l_E-l_M)+(l_E-l_M)(2+l_E+l_M)^2t\right]}{18t(l_E-l_M)}\right],$$
$$\pi_E(p,l_M,l_E) = (1-p)\frac{[c_E-c_M+t(l_E-l_M)(l_E+l_M-4)]^2}{18t(l_E-l_M)}.$$

At the second stage, firms decide locations $l_M, l_E$ which in equilibrium satisfy the first order conditions:

$$\frac{\partial\pi_M(p,l_M,l_E)}{\partial l_M} = (1-p)\frac{[(c_E-c_M)+(l_E-l_M)(l_E-3l_M-2)t][(c_E-c_M)+(l_E+l_M)(2+l_E+l_M)t]}{18t(l_E-l_M)^2} = 0;$$
$$\frac{\partial\pi_E(p,l_M,l_E)}{\partial l_E} = (1-p)\frac{[(c_M-c_E)+(l_E-l_M)(3l_E-l_M-4)t][(c_M-c_E)-(l_E-l_M)(l_E+l_M-4)t]}{18t(l_E-l_M)^2} = 0.$$

Solving this system, we obtain equilibrium locations as a function of the marginal cost of the service,

$$l_M^2 = \frac{c_E-c_M}{3t} - \frac{1}{4} \quad l_E^2 = \frac{c_E-c_M}{3t} + \frac{5}{4}.$$

Substituting $r_M\ (l_M, l_E)$ and $r_E(l_M, l_E)$ into the profit functions of the monopolist and the entrant firm respectively, we obtain second stage equilibrium profits,

$$\pi_M(p) = (1-p)\left[\frac{16(c_M-c_E)^2+108t(p+\alpha-k)-72t(c_M-c_E)+81t^2}{108t}\right],$$
$$\pi_E(p) = (1-p)\frac{[4(c_M-c_E)+9t]^2}{108t}.$$

Finally, at the first stage, the network owner $M$ sets $p$ to satisfy the first order condition,

$$\frac{\partial\pi_M(p)}{\partial p} = (1-p) - \pi_M(p) = 0,$$

which yields $p_M^2 = \frac{12(1+k-\alpha)-3t}{8} + \frac{(c_M-c_E)(9t-2c_M+2c_E)}{27t}$. This completes the proof. ■

## 6.4 Proof of Proposition 4

**Proof.** At the retail stage $M$ and $E$ set retail prices which in equilibrium satisfy the first order conditions:

$$\frac{\partial\pi_M(r_M,r_E,p)}{\partial r_M} = (1-p)\frac{(\alpha+c_M+r_E-2r_M+t)}{2t} = 0;$$
$$\frac{\partial\pi_E(r_M,r_E,p)}{\partial r_E} = (1-p)\frac{(\alpha+c_E+r_M-2r_E+t)}{2t} = 0,$$

whose simultaneous solution yields retail prices $r_M^3 = c_M + \frac{2(k+1)+t}{2} - \frac{(c_M-c_E)^2}{18t}$ and $r_E^3 = \frac{2(k+1)+t}{2} + \frac{6t(2c_M+c_E)-(c_M-c_E)^2}{18t}$. Substituting $r_M^3$ and $r_E^3$ into the profits functions of the monopolist and the entrant firm we obtain second stage profits:

$$\pi_M(p) = (1-p)\frac{(c_E-c_M)^2+18t(1+\alpha-k)+6t(c_E-c_M)+9t^2}{18t},$$
$$\pi_E(p) = (1-p)\frac{(c_M-c_E+3t)^2}{18t}.$$

Finally, at the first stage, the monopolist decides $\alpha$, and $p$ which in equilibrium satisfy the conditions:

$$\frac{\partial \pi_M(p)}{\partial \alpha} = (1-p) > 0;$$
$$\frac{\partial \pi_M(p)}{\partial p} = (1-p) - \pi_M(p) = 0.$$

Observe that the first of the two partial derivatives above is always larger than zero provided that the $p \in [0,1)$. Then, the maximal value of $\frac{\partial \pi_M(p)}{\partial \alpha}$ is reached when $p_M^3 = 0$. Consequently, we substitute $p_M^3 = 0$ along the optimal path obtained from $\frac{\partial \pi_M(p)}{\partial p}\rfloor_{p_M^3=0} = 0$, which yields $\alpha^3 = \frac{2(k+1)-t}{2} + \frac{6t(c_M-c_E)-(c_M-c_E)^2}{18t}$. This completes the proof. ■

## 6.5 Proof of Proposition 5

**Proof.** At the third and second stages firms set retail prices and locations in the same way as in the case 2. Then, calculations are the same as in Proposition 3, except that in the first stage the network monopolist sets $\alpha$ and $p$. Second stage profits are:

$$\pi_M(p) = (1-p)\left[\frac{16(c_M-c_E)^2+108t(p+\alpha-k)-72t(c_M-c_E)+81t^2}{108t}\right],$$
$$\pi_E(p) = (1-p)\frac{[4(c_M-c_E)+9t]^2}{108t}.$$

Finally, at the first stage, the monopolist decides $\alpha$, and $p$ which in equilibrium satisfy the conditions:

$$\frac{\partial \pi_M(p)}{\partial a} = (1-p) > 0;$$
$$\frac{\partial \pi_M(p)}{\partial p} = (1-p) - \pi_M(p) = 0,$$

and solving in the way of the previous proof, the first of the two partial derivatives is always larger than zero provided that $p \in [0,1)$. Then, the maximal value of $\frac{\partial \pi_M(p)}{\partial \alpha}$ is reached when $p_M^4 = 0$. Consequently, we substitute $p_M^4 = 0$ along the optimal path obtained from $\frac{\partial \pi_M(p)}{\partial p}\rfloor_{p_M^4=0} = 0$, which yields $\alpha^4 = \frac{4(k+1)-3t}{4} + \frac{18t(c_M-c_E)-4(c_M-c_E)^2}{27t}$. This completes the proof. ■

# References


[1] Aguilar, J. and I. Herguera (2004), “Interconnection by Capacity”, mimeo.

[2] Armstrong, M. (1998), "Network Interconnections in Telecommunications", *The Economic Journal* 108, 545-564.

[3] Behringer, S. (2004), “Entry, Access Pricing, and Welfare in the Telecommunication Industry”, mimeo.

[4] De Bijl, W.J. and M. Peitz (2002), “Regulation and Entry into Telecommunications Markets”, *Cambridge University Press*, Cambridge, UK.

[5] De Bijl, W.J. and M. Peitz (2005), "Local Loop Unbundling in Europe: Experience, Prospects and Policy Challenges", Tilec discussion papers, DP 2005-008, ISSN 1572-4042.

[6] De Bijl, W.J. and M. Peitz (2006), "Local Loop Unbundling: One-Way Access and Imperfect Competition", in R. Dewenter and J. Haucap (eds.), *Access Pricing: Theory and Practice*, Elsevier Science.

[7] D’Aspremont, J., Gabszewicz, J. and J-F. Thisse (1979), “On Hotelling’s ‘Stability in Competition”’. *Econometrica* 47, 1145-1150.

[8] Dessein, W. (2003), “Network Competition in Nonlinear Pricing”, *RAND Journal of Economics* 34, 1–19.

[9] Greenstein, S. and M. Mazzeo (2006), “The Role of Differentiation Strategy in Local Telecommunication Entry and Market Evolution: 1999-2002”, *Journal of Industrial Economics* 54, 323-350.

[10] Gutiérrez-Hita, C. and M. Peitz (2001), “Retailer Locations, Local Supply, and Price Policies”, *Instituto Valenciano de Investigaciones Económicas* Working Papers-AD series, C7, 414-466.

[11] Hotelling, H. (1929), “Stability in Competition”, *Economic Journal* 39, 41-57.

[12] Peitz, M. (2005a), “Asymmetric Access Price Regulation in Telecommunication Markets”, *European Economic Review* 49, 341-358.

[13] Peitz, M. (2005b), “Asymmetric Regulation of Access and Price Discrimination in Telecommunications”, *Journal of Regulatory Economics* 28, 327-343.

[14] Schiff, A. (2002), “Two-way Interconnection with Partial Consumer Participation”, *Networks and Spatial Economics* 2, 295-315.

[15] Vogelsang, I. (2003), "Price Regulation of Access to Telecommunications Networks", *Journal of Economic Literature* 41, 830-862.