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Universal service obligations in the postal sector: The relationship between quality and coverage

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ABSTRACT

This paper examines competition in the postal sector when one private incumbent and one entrant play a three-stage game. First, firms choose their coverage. Then, they choose the quality of the mail. Finally, firms choose the price. I modify the traditional model of product differentiation proposed by Mussa and Rosen [Mussa, M., Rosen, S., 1978. Monopoly and product quality. Journal of Economic Theory 18, 301–317] in order to consider that firms decide their quality and coverage. Valletti et al. [Valletti, T., Hoernig, S., Barros, P., 2002. Universal service and entry: the role of uniform pricing and coverage constraints. Journal of Regulatory Economics 21 (2), 169–190] show that when an incumbent is regulated by a uniform pricing constraint the entrant will choose a low level of coverage to increase the incumbent's uniform price and weaken competition. In this paper, I show that by increasing product differentiation, the entrant can obtain the same price increase with a smaller reduction of coverage. Acknowledgement of the strategic link between quality and coverage can be very useful in the design of a regulatory policy. The paper also considers a mixed duopoly in which the public firm covers the entire market and offers high quality service. In this context, I explain that the mixed equilibrium implements the first-best qualities and coverage levels.

1. Introduction

In a liberalized postal market, Universal Service Obligations (USOs) guarantee that all consumers have access to a basic package of services at affordable uniform prices and that the services have a minimum level of quality.[1] However, the viability of the USO may be threatened when entrants limit service to profitable mailers, opt for niche markets or choose product differentiation strategies. This paper analyzes the conduct of firms in a competitive postal market when one firm is regulated to provide some universal services. My objective is to understand how the imposition of a uniform price affects firms quality and coverage decisions and, also, to assess whether minimum quality standards and coverage obligations might usefully increase welfare.

An important contribution of this paper is its recognition that firms are able to determine both quality and coverage. To my knowledge, the analysis of the relationship between quality and coverage has not been addressed in the literature before, and can be useful for guiding public intervention in network industries. Recent contributions to the study of universal service obligations such as Valletti et al. (2002) show that when an incumbent operator is required to provide a uniform price, the entrant seeks to weaken competition by strategically covering only part of the country. In this paper, I explain that when the entrant can modify its quality of service, it chooses a larger area of coverage than when quality is fixed. In general, firms pre-

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[1] The analysis of the universal service in network industries was initiated by Crew and Kleindorfer (1998, 2005), Laffont and Tirole (2000), Gasmi et al. (2000), Cremer et al. (1998, 2001, 2007) and Armstrong (2001) among others. Rosston and Wimmer (2000) compare different public programs to provide the universal service in the telecommunications sector.

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fer increasing product differentiation over reducing coverage when attempting to reduce competition.

A second contribution of this paper is to extend the product differentiation model developed by Mussa and Rosen (1978) in order to study the strategic link between quality and coverage. I analyze the competition between one incumbent firm and one entrant engaged in a three-stage game. In the first stage, firms choose their coverage area. In the second, firms determine the quality of the mail and, in the third stage, set the price. This framework allows me to identify how firms coverage choices influence their quality decisions.

An entrant's equilibrium coverage is the result of two opposing forces. The entrant prefers wide coverage in order to reach more consumers. However, if the incumbent charges a uniform price, then the entrant may have an interest in restricting its coverage. In such a case, the incumbent, effectively the monopolist of the region not covered by the entrant, will establish a higher price than the duopoly price, thus allowing the entrant to charge a higher price. In a private duopoly, the second effect dominates, and as a consequence, the entrant covers only part of the country.

Equilibrium quality determinations are also the consequence of two opposing forces. The firms interest in supplying the quality variety that is most profitable in terms of consumer preferences and costs will tend to make firms choose the same quality level. However, firms in equilibrium commercialize different services because product differentiation weakens price competition and raises profits. The main result presented in this paper is that a difference in coverage increases the extent to which firms differentiate products. When the entrant covers only part of the country, competition is moderated and firms are able to increase their prices. In this situation, the larger the difference between the incumbent and the entrant's coverage, the greater the profit that they will both obtain by increasing product differentiation.

This conclusion complements previous research on the effects of uniform prices in liberalized markets. It implies that an entrant's coverage strategy depends upon its ability to modify the quality of services. Moreover, this result alerts regulators to the need to establish minimum quality requirements in order to reduce inefficient quality differentiation and keep prices down.[2] Thus, while imposing a minimum quality requirement on the entrant is welfare-enhancing, limiting the quality of the incumbent moderates product differentiation and reduces welfare. In addition, this paper demonstrates the benefits of complementing quality regulations with minimum coverage requirements.

This paper also analyzes competition in a mixed duopoly. In the European Union, some countries such as Belgium, Germany and Netherlands, have partially privatized the incumbent postal operators, and in Argentina and Japan the government have completely privatized them.[3] Nevertheless, at present, the most common form of postal market competition is between a public incumbent and one or several private entrants. Taking this scenario into account, I analyze the conduct of firms in a mixed duopoly and I show that the presence of a public firm has two remarkable effects: first, firms set their qualities efficiently; second, entrants have incentives to cover a greater part of the country. These results are interesting for regulatory policy because they indicate that the presence of a public firm can, by itself, be enough to improve equilibrium quality and coverage allocations.

Finally, the last part of the paper analyzes the conduct of firms in the presence of network externalities. The importance of network externalities has been neglected in previous analyses of the USO. In my model, network externalities appear when senders value the size of a firm's distribution network.[4] Cremer et al. (2001) consider a duopoly in which the senders see the size of the network as a quality attribute. They show that the larger the entrant's coverage, the lower the price differential at which the entrant can capture a positive market share. Following this idea, the present paper considers that mail service has two quality attributes, the intrinsic quality of mail (frequency of delivery and reliability) and coverage. This extension is useful to show how firms use their coverage as a substitute for the intrinsic quality of the mail. When network externalities are important, the entrant prefers a wide coverage in order to increase the valuation of the service. Therefore, network externalities might compensate for the distortions of the entrant's coverage that are created by the imposition of a uniform price on the incumbent.

The results of this paper are connected with the previous literature about USOs in the postal sector. Nevertheless, very few papers have taken into consideration the quality of the mail. Crew and Kleindorfer (1998) develop a model that simultaneously determines USOs characteristics and the reserved area necessary for an incumbent to finance the USOs. The importance of quality is also highlighted by Crew and Kleindorfer (2005) when they claim that "it seems unlikely for most countries that letter-mail USO can be supported without a reserved area, unless service standards are relaxed."

Although the previous papers explicitly consider the quality of mail, the present analysis is more closely related to the model of vertical product differentiation developed by Cremer et al. (1997). These authors consider a duopoly that plays a two-stage game: first firms choose qualities and then prices. In this context, private duopolies result in an inefficient provision of quality. However, if one firm is public, the equilibrium qualities are close to the first best.[5] In my model, the duopolists choose the coverage level, the quality of the mail and the prices. As a result, I

[2] Cremer et al. (1997) and Valletti et al. (2002) analyze the imposition of minimum quality standards.

[3] See Bel and Calzada (2007) for an analysis of the privatization in the postal sector.

[4] I do not consider the access problem. Many incumbent postal regulators offer worksharing discounts to mailers. However, at present, only the UK and Germany regulate some types of access charges. See WIK (2005) and Calzada (2009).

[5] Cremer et al., 1991 analyze a mixed oligopoly with horizontal product differentiation in which the firms chose their locations and prices in a model *a la* Hotelling. The authors study how the number of public firms competing with private firms affects social welfare.

can identify the effect of coverage on the quality provided by the firms.

The present paper is also closely tied to the work of Valletti et al. (2002). These authors show that the imposition of a uniform price on an incumbent telecommunications operator critically affects the ratio between the entrant's and the incumbent's coverage. This happens because the entrant wants to enlarge the incumbent's monopoly region in order to increase its uniform price. The authors demonstrate that a uniform price creates a strategic link between the monopoly region covered by the incumbent and the duopoly region covered by the two firms. Under a uniform price the entrant chooses to serve a smaller area than the incumbent in order to reduce competition. In this paper, I show that the effect of a uniform price persists when firms determine both the quality of the mail and their coverages. In this case, however, as product differentiation depends upon the firms' relative coverage, the entrant can obtain the same increase of the incumbent's uniform price with a smaller reduction of its own coverage.

Finally, Fabra et al. (2004) consider competition in a private duopoly in which the incumbent covers the entire population and has a regulated uniform price. The entrant is free to decide its coverage and can price discriminate with respect to the path of the letter mail. However, in their model the qualities are set exogenously. The duopolists play a two-stage game. First, the regulator establishes the incumbent's uniform price and a transfer payment that covers the incumbent's costs. Second, after having observed the incumbent's price, the entrant chooses its coverage and the price for each path. The authors conclude that the higher the entrant's quality advantage, the larger the coverage that the entrant choose. In my paper, by contrast, product differentiation depends on the firms coverage levels. Moreover, I assume that both firms establish uniform prices. This assumption restricts the entrant's strategy, but it reflects the present situation in many liberalized markets, such as those in Sweden and Spain.

The remainder of the paper is organized as follows. Section 2 explains the main features of the model. Section 3 presents the optimal qualities and coverage levels that a benevolent regulator would establish. Section 4 considers a private duopoly when the incumbent covers the entire market and must establish a uniform price. Sections 5 analyzes the effect of imposing different quality and coverage obligations on the firms. Section 6 analyzes the strategies of firms in a mixed duopoly. Section 7 analyzes the interaction between quality and coverage in the presence of network externalities and Section 8 concludes the paper.

2. The model

Consider one incumbent postal operator ($i = 1$) and one entrant ($i = 2$) that commercialize a postal service. The duopolists can potentially serve a continuum of villages $[0, \overline{\mu}]$, where $\overline{\mu}$ represents the size of the country. All villages have the same population, but different extensions. As a result, if consumers in a village are uniformly distributed over space, then the villages can be ordered according to their increasing coverage costs. If firm i covers all villages until μ_i, it pays $F(\mu_i)$, where $F(0) = 0$, $F'(\mu_i) = f(\mu_i) > 0$ and $F''(\mu) > 0$. We assume that the two firms face the same costs of coverage.

For simplicity, assume that $\mu_1 = \overline{\mu} = 1$ and that the entrant's coverage is always smaller than the incumbent's; that is $K = 1/\mu_2 > 1$.[6] As a result, the region $[0, \mu_2]$ is served by the duopolists and the region $(\mu_2, 1]$ is monopolized by the incumbent. Also for simplicity, assume that all letters are addressed to the sender's own village. Section 7 relaxes this assumption and allows consumers to send letters to any other village. This modification is useful in analyzing the effect of network externalities.

Vertical differentiation is introduced following the model of Cremer et al. (1997).[7] In this paper, I call $x_i \geqslant 0$ the quality of the letters supplied by a firm i. I assume that the incumbent offers a higher quality than the entrant, $x_1 > x_2$. This assumption is frequently satisfied in the postal sector, since incumbents deliver letters more frequently than do their competitors. Throughout the text, I will discuss the consequences of modifying this assumption.

The preference of senders for a given quality of the mail is represented by θ, which is uniformly distributed in the segment $[\underline{\theta}, \overline{\theta}]$. For simplicity, assume that all villages have a continuum of senders, such that $\overline{\theta} - \underline{\theta} = 1$. In addition, imagine that the senders have a perfectly inelastic demand that is normalized to one unit. Thus, the surplus of a sender with type θ who sends one letter of quality x_i at price p_i is given by $\theta x_i - p_i$.[8]

Firms operate in a liberalized market and are free to choose their prices and qualities. This framework reflects the current situation in the EU postal market, in which the incumbents have significant commercial autonomy. However, the incumbents must satisfy several universal service obligations. For example, they must charge a uniform and affordable price that guarantees that all consumers will have access to the service in the villages covered by the incumbent. Moreover, incumbents have some coverage obligations.

Taking into account the qualities and prices established by the duopolists, one sender with type $\widetilde{\theta}$, located in one village of the duopoly region, is indifferent between the incumbent and the entrant when the following condition is satisfied:

$$\widetilde{\theta} x_1 - p_1 = \widetilde{\theta} x_2 - p_2. \tag{1}$$

Therefore, the incumbent's demand in the villages covered by the two firms is:

$$\overline{\theta} - \widetilde{\theta} = \overline{\theta} - \frac{p_1 - p_2}{x_1 - x_2}. \tag{2}$$

[6] This assumption reflects the present situation in the postal sector. For historical reasons, one firm (usually the incumbent) has a larger coverage than its rival. This simplification reduces the number of cases that need to be analyzed. Note, however, that if both firms freely choose coverage areas, a pure strategy equilibrium might not exist.

[7] This paper is based on an specification introduced by Mussa and Rosen (1978) and developed in Cremer and Thisse (1994). In contrast to Cremer et al. (1997), I do not consider the utility of addresses in this model.

[8] Observe that the model do not consider the presence of an outside option. In practice, mail competes with other communication services such as the telephone or Internet. Clearly, a complete analysis of the postal market would require considering competition among different communication modes, and the universal service obligations established for each service.

Bearing the above result in mind, in these duopoly villages the entrant's demand can be written as $\widetilde{\theta} - \underline{\theta}$. Therefore, in the duopoly region, the senders with a high preference for quality buy from the incumbent, while those with a low preference for quality buy from the entrant.

Assuming that the two firms have the same technology, then a firm's marginal cost of providing letters is $C(x_i) = \frac{cx_i^2}{2}$. This cost is independent of the quantity provided, but is quadratic with respect to the quality.

Finally, I consider that firms play a three-stage dynamic game. First, the entrant sets its coverage, taking into account that the incumbent covers the whole country. Second, bearing in mind their relative coverage, firms choose the quality of letter services. Finally, the firms set prices. The solution concept that I use for solving this game is the subgame perfect Nash-equilibrium.

3. Optimal allocations

This section analyzes the optimal levels of quality and coverage that a benevolent regulator would establish in order to maximize welfare. This result is later used as a benchmark in order to assess the unregulated market equilibrium. In the first stage of the game, the regulator chooses the entrant's coverage, taking into account that the incumbent covers the entire country. In the second stage, the regulator sets the duopolists' optimal qualities. The regulator's social welfare function is the unweighted sum of the consumer surplus and the profit of the firms. Assuming that both variants of the service are sold at marginal cost, the welfare function is as follows:[9]

$$W = \mu_2 \left[\int_{\underline{\theta}}^{\overline{\theta}} \left(\theta x_1 - \frac{cx_1^2}{2} \right) \mathrm{d}\theta + \int_{\underline{\theta}}^{\widetilde{\theta}} \left(\theta x_2 - \frac{cx_2^2}{2} \right) \mathrm{d}\theta \right] + (\mu_1 - \mu_2) \int_{\underline{\theta}}^{\overline{\theta}} \left(\theta x_1 - \frac{cx_1^2}{2} \right) \mathrm{d}\theta - F(\mu_2) - F(1). \quad (3)$$

The next proposition shows the entrant's coverage and the quality levels that solve the regulator's problem. (See the proof in the Appendix.)

Proposition 1. *Given the firms' relative coverages,* $K = \frac{1}{\mu_2}$, *the incumbent's and entrant's optimal qualities are:*

$$x_1^o = \frac{8\underline{\theta} + 9K - 3(9K^2 - 8K)^{\frac{1}{2}}}{8c};$$
$$x_2^o = \frac{8\underline{\theta} + 3K - (9K^2 - 8K)^{\frac{1}{2}}}{8c}. \quad (4)$$

When $\overline{\mu} = 1$, *the entrant's optimal coverage satisfies:*

$$\mu_2^o = \frac{[32^2 cf(\mu_2)]^{\frac{1}{3}} - 2^{\frac{1}{3}}}{[4c^2 f(\mu_2)^2]^{\frac{1}{3}}}. \quad (5)$$

Observe that with a duopoly, the regulator sets different qualities for each firm. As a consequence, senders are able to find a product that more closely meets their preferences.

Another insight from this proposition is that the optimal quality allocations depend upon the firm's relative coverage (see Fig. 1).[10] Since the incumbent is not allowed to offer a different quality level in each region, its uniform optimal quality is a convex combination of the optimal monopoly and duopoly levels. When the entrant has a smaller coverage than the incumbent, the incumbent's uniform quality is smaller than in the case when both firms have the same coverage, because in this situation there are fewer customers with access to the two variants of the service. In fact, when the incumbent's monopoly region is large, a reduction of the incumbent's uniform quality enhances the welfare of consumers located in the monopoly region. While such a reduction in the incumbent's quality worsens the situation of consumers with a higher preference for quality, it benefits those consumers with a low quality preference located in the monopoly region.

Note, in addition, that the regulator establishes the quality of firms that optimize the level of product differentiation.

Finally, Eq. (5) is obtained after substituting the optimal quality levels of Eq. (4) into the welfare function and differentiating with respect to the entrant's coverage level. Observe that when the marginal coverage cost is sufficiently small (i.e. $f(\mu_2) < \frac{1}{2c}$), the entrant covers the entire country. However, when the marginal coverage cost is large, it is inefficient to duplicate the incumbent's network in all villages.

4. Private duopoly under uniform price and quality constraints

This section develops a competition model between one incumbent postal operator covering the entire country and one entrant. The duopolists are unregulated, but we assume that they must offer an affordable uniform price to all consumers and a uniform quality in all villages. As a consequence, the incumbent serves everybody in the monopoly region, and the two operators serve all consumers in the duopoly region. The duopolists play a game in three stages. Firstly, the entrant decides its coverage, then the two firms fix the quality and, finally they set the price.

4.1. Third stage: determination of prices

In the third stage of the game the duopolists set the prices taking into account that quality and coverage levels have already been decided. The incumbent is a monopolist in the region (μ_2,1] and a duopolist in the region [0,μ_2]. Bearing this in mind, its uniform price takes a value between the duopoly and the monopoly price. The incumbent's uniform price maximizes the sum of profits obtained in the duopoly and the monopoly regions, $\Pi_1 = \pi_1^{\mathrm{m}} + \pi_1^{\mathrm{d}}$.

[9] Notice that with the first best prices, firms make a loss equal to $F(\mu_i)$. In this situation, a regulator who cares about the budget equilibrium of firms must establish higher prices.

[10] Only when $K = 1$ (i.e. when the two firms have identical coverage) are the optimal quality levels the same as in the standard model of product differentiation developed by Moorthy (1988) and Cremer and Thisse (1994).

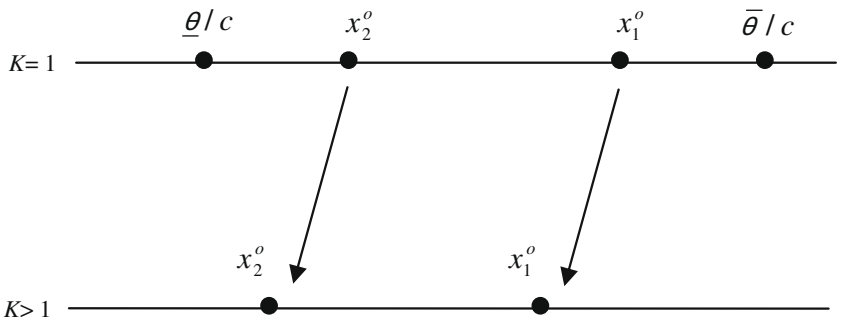

Fig. 1. Optimal quality allocations.

$$\underset{\{p_1\}}{\text{maximize}} \quad \Pi_1 = \mu_2\left(p_1 - \frac{cx_1^2}{2}\right)\left(\overline{\theta} - \frac{p_1 - p_2}{x_1 - x_2}\right) + (1-\mu_2)\left(p_1 - \frac{cx_1^2}{2}\right)\left(\overline{\theta} - \frac{p_1}{x_1}\right) - F(1), \tag{6}$$

Subject to the affordability constraint: $\underline{\theta}\, x_1 - p_1 \geqslant 0$.

The affordability constraint is a universal service obligation imposed on the incumbent's price.[11] It requires that p_1 and x_1 are set in such a way that all consumers are able to access the incumbent's service. Notice that when this constraint is solved with an equality it is satisfied that $\underline{\theta} = p_1/x_1$. In this situation, the number of senders that buy from the incumbent in the monopoly region is $(\overline{\theta} - \frac{p_1}{x_1}) = 1$.

The entrant obtains profits only from the duopoly region.

$$\underset{\{p_2\}}{\text{maximize}} \quad \Pi_2 = \mu_2\left(p_2 - \frac{cx_2^2}{2}\right)\left(\frac{p_1 - p_2}{x_1 - x_2} - \underline{\theta}\right) - F(\mu_2). \tag{7}$$

By differentiating the profit function of the two firms with respect to the prices and rearranging the first-order conditions I obtain the following prices:

$$p_1 = \frac{1}{3}[(x_1 - x_2)(2\overline{\theta} - \underline{\theta}) + \frac{c}{2}(2x_1^2 + x_2^2) + 2(x_1 - x_2)(K-1)];$$
$$p_2 = \frac{1}{3}[(x_1 - x_2)(\overline{\theta} - 2\underline{\theta}) + \frac{c}{2}(2x_2^2 + x_1^2) + (x_1 - x_2)(K-1)]. \tag{8}$$

Note that as we assume that $x_1 > x_2$ and $K \geqslant 1$, the incumbent's price is always higher than the entrant's. A more in-depth analysis of the prices in (8) yields the following result.

Proposition 2. *Equilibrium prices depend on letter qualities and relative coverage K. Under a uniform pricing constraint, p_1 and p_2 increase with quality x_1, and decrease with letter quality x_2 when the entrant's marginal cost of quality is small. An increase of x_1 increases both the incumbent's profits in the monopoly region, π_1^{m}, and the entrant's profits, Π_2. It can also increase the incumbent's profits in the duopoly region, π_1^{d}, if this region is sufficiently large. An increase of x_2 produces the opposite effects.*

An increase in the incumbent's quality raises its price. This increase occurs for two reasons. First, an increase in quality raises costs, and second, product differentiation increases. Similarly, an increase in the incumbent's quality raises the entrant's price because the incumbent has greater costs and services are more differentiated. As services become more different, competition weakens. In contrast, an increase in the entrant's quality raises its costs, but reduces the product differentiation. Therefore, the prices may be reduced.

On the other hand, an increase of $K = 1/\mu_2$ enlarges the monopoly region and leads the incumbent to set its uniform price closer to the monopoly price. This effect allows the entrant to increase its price as well.

Focussing on profits, an increase in the incumbent's quality (and a reduction in the entrant's quality) increases product differentiation and raises both the entrant's and the incumbent's profits in the monopoly region. However, the incumbent's profit in the duopoly region can be reduced if the size of the region is small. In fact, higher quality delivered by the incumbent raises the entrant's price and, as a result, the incumbent can increase profits in the duopoly region. However, increasing the quality of the incumbent's services also raises the incumbent's uniform price, which can reduce the incumbent's profit in the duopoly region. When the entrant's coverage is small, the second effect dominates.

4.2. Second stage: determination of quality levels

In the second stage of the game, the duopolists establish the qualities of deliveries, taking into account the relationship between qualities and prices. Substituting the prices in (8) into the profit functions yields:

$$\underset{\{x_1\}}{\text{maximize}} \quad \Pi_1 = \frac{\mu_2(x_1 - x_2)}{9}[(2\overline{\theta} - \underline{\theta}) + \frac{c}{2}(x_1 + x_2) + 2(K-1)]^2 - F(1); \tag{9}$$

$$\underset{\{x_2\}}{\text{maximize}} \quad \Pi_2 = \frac{\mu_2(x_1 - x_2)}{9}[(\overline{\theta} - 2\underline{\theta}) + \frac{c}{2}(x_1 + x_2) + (K-1)]^2 - F(\mu_2). \tag{10}$$

[11] The affordability constraint reduces the ability of firms to increase prices. As it will become clear later, this constraint limits the entrant's incentives of strategically modifying its coverage and quality to increase the incumbent's price.

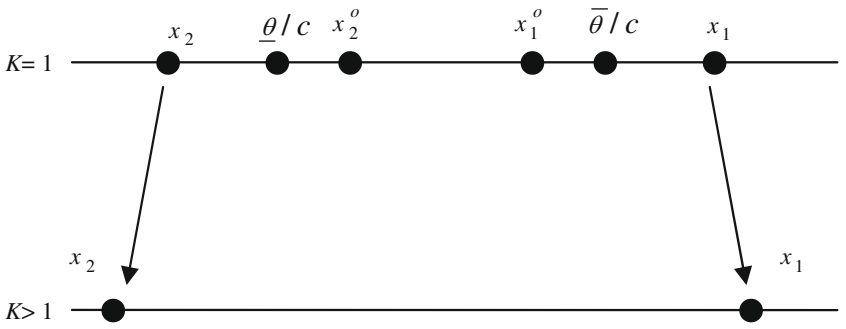

Fig. 2. Equilibrium quality allocations in a private duopoly.

Solving the first order conditions of these problems, I obtain the qualities that are chosen by the incumbent and the entrant:

$$x_1 = \frac{4\underline{\theta} + 5K}{4c}; \quad x_2 = \frac{4\underline{\theta} - K}{4c}. \tag{11}$$

Comparing these qualities with the optimal qualities in (4), I observe that, for $K > 0$, the incumbent's quality is always higher than the optimal, while the entrant's quality is lower (see Fig. 2) . This result generalizes the conclusion of Cremer et al. (1997), who find that private firms choose a higher than optimal level of product differentiation in order to reduce competition. By increasing product differentiation, firms are able to set higher prices and obtain greater profits. Observe that by substituting the qualities in (11) into the equations in (8), I obtain prices in both cases that are higher than the marginal costs:

$$p_1 = \frac{16\underline{\theta}^2 + 40\underline{\theta}K + 49K^2}{32c};$$
$$p_2 = \frac{16\underline{\theta}^2 - 8\underline{\theta}K + 25K^2}{32c}. \tag{12}$$

The letter qualities in (11) allow one to characterize the relationship between the level of product differentiation and the relative coverage of the firms.

Proposition 3. *Regardless of which of the two firms provides the highest quality, an increase of the relative coverage, K, raises the product differentiation.*

Proposition 3 shows that firms adapt qualities to the level of relative coverage. A direct observation of the qualities in (11) shows that an increase of K increases the quality of the high-quality firm and reduces the quality of the low-quality firm. When the entrant reduces its coverage (i.e. K increases), the incumbent's monopoly region grows and, as a consequence, the incumbent sets a uniform price closer to the monopoly price. Therefore, firms are more able to increase product differentiation when the entrant reduces its coverage.

The relationship between relative coverage and product differentiation takes place regardless of which firm (the incumbent or the entrant) offers the higher-quality service. Indeed, the entrant always finds it profitable to cover a smaller number of villages than the incumbent in order to increase product differentiation since the entrant compensates for the small coverage level with a higher price in the duopoly villages.

This result has interesting policy implications. It is a well-known conclusion of the literature on vertical differentiation that private firms increase product differentiation in order to weaken competition.[12] Proposition 3 shows that firms can also increase product differentiation by modifying coverage. When the entrant covers a smaller number of villages than the incumbent, competition is weakened and the two firms can increase product differentiation and set higher prices.

Finally, the following proposition further characterizes the firms' optimal behavior in terms of quality.

Proposition 4. *For the incumbent and the entrant, the quality levels are strategic complements:*

$$\frac{dx_1}{dx_2} = \frac{dx_2}{dx_1} = \frac{1}{3} > 0. \tag{13}$$

For any given K, the increase in one firm's quality increases the quality offered by the other firm, although in a smaller proportion. When the entrant increases its quality, the incumbent reacts by increasing its quality in order to moderate the reduction of product differentiation, although the incumbent does so less than proportionately in order to protect its market share. Similarly, when the incumbent increases its quality level, the entrant increases its own quality, although less than proportionately because the entrant benefits from an increase in product differentiation.

4.3. First stage: determination of the entrant's coverage level

Next, I analyze how the entrant chooses its coverage in the first stage of the game. Considering the quality levels in (11), we can simplify the entrant's problem as follows:

$$\underset{\{\mu_2\}}{\text{maximize}} \quad \Pi_2 = \frac{\mu_2}{9c}\left(\frac{3K}{2}\right)^3 - F(\mu_2). \tag{14}$$

Differentiating the entrant's profit function with respect to its coverage level I obtain its equilibrium coverage. Taking this and the consumer's affordability restriction into

[12] See for instance Moorthy (1988), Cremer et al. (1991), Cremer and Thisse (1994) and Cremer et al. (1997).

account, I can derive the duopolists' relative coverage. The next proposition characterizes the duopolists' profit-maximizing allocations.

Proposition 5. *When the incumbent supplies the high quality service, the duopolists offer the following prices, qualities and coverage levels:*

$$\begin{aligned} p_1^e &= \frac{12\underline{\theta}^2}{7c}; \quad p_2^e = \frac{30\underline{\theta}^2}{49c}; \\ x_1^e &= \frac{12\underline{\theta}}{7c}; \quad x_2^e = \frac{6\underline{\theta}}{7c}; \\ \mu_2^e &= \frac{7}{4\underline{\theta}}; \quad K^e = \frac{4\underline{\theta}}{7} > 1. \end{aligned} \tag{15}$$

This proposition reveals that the entrant chooses a smaller coverage than the incumbent and therefore $K^e > 1$.[13] In order to understand how K^e is determined, note from the first-order condition of Eq. (14) that the entrant prefers to reduce its coverage as much as possible, because this reduction enlarges the incumbent's monopoly region and allows it to set higher prices. However, the equilibrium relative coverage must guarantee that all consumers are able to access the service. When $K = 4\ \underline{\theta}/7$, if the incumbent increases its price, then some senders will cease their consumption. In this situation, the entrant will not be interested in reducing its coverage any further because such a reduction would leave the incumbent's uniform price unaltered. Therefore, K^e is the equilibrium relative coverage.

The result of the proposition contrasts with the optimal coverage level found in Proposition 1. While a benevolent regulator extends the entrant's coverage to the point at which the coverage costs are equal to the marginal benefit given to the consumers, an unregulated entrant prefers a smaller coverage, which allows the entrant to fix higher prices.

The coverage strategy of the entrant has two effects: (a) the incumbent is the monopolist for a group of villages and establishes a higher uniform price; and (b) as the duopolists have different coverage levels, they are able to increase product differentiation more than two firms with the same coverage would. As a consequence, the entrant's quality is inefficiently set below the optimal allocation defined in Eq. (4) and the incumbent's quality is inefficiently set above the optimal level.

Another consequence of Proposition 5 is that the entrant obtains greater profits than the incumbent. Clearly, when $\mu_2 < \overline{\mu} = 1$, the entrant earns a larger profit.[14]

$$\Pi_1 = \frac{\mu_2}{9c}\left(\frac{3K}{2}\right)^3 - F(1), \tag{16}$$

$$\Pi_2 = \frac{\mu_2}{9c}\left(\frac{3K}{2}\right)^3 - F(\mu_2). \tag{17}$$

This situation reflects the fact that the entrant has more power in determining the incumbent's price and quality than vice versa. Interestingly, this advantage for the entrant appears regardless of which of the two firms provides the higher quality service. In fact, the entrant always prefers to increase K in order to raise the incumbent's uniform price.

5. Quality and coverage regulation

The previous analysis has shown that private duopolists choose an inefficient level of product differentiation; the quality level supplied by the entrant is too low and that supplied by the incumbent is too high. Next I will analyze the welfare impact of bringing the firms' qualities of service closer to the optimal allocations as described in Proposition 1. I assess the effect of regulating the service quality of the firms assuming that the regulator sets those qualities before the entrant has decided its coverage level. In addition, I assume that the entrant's coverage cost is so high that in equilibrium it always chooses a coverage level that makes the incumbent satisfy the affordability condition with an equality.

Table 1 illustrates the welfare changes produced by the regulation of quality. The first line shows the consumer's surplus and the firm's profits generated in an unregulated scenario. The second line shows the impact of reducing the incumbent's quality by 10% and the third line shows the effect of increasing the entrant's quality by 10%.

Result 1. A 10% reduction of the incumbent's quality below x_1^e reduces the entrant's equilibrium quality to a smaller proportion and reduces the entrant's coverage level. Compared to the unregulated case, the incumbent's and the entrant's consumers receive lower quality service and pay less for it. Also, however, their surplus is reduced.

Proposition 4 has shown that a reduction in the incumbent's quality reduces the entrant's equilibrium quality, although in smaller proportion. Therefore, the result of a 10% reduction in the incumbent's quality is a reduction in product differentiation that consequently cuts prices. The entrant also reacts by choosing a smaller area of coverage, but this effect is not enough to increase the price to the previous level. Note also that with the new equilibrium allocations, some of the entrant's consumers in the duopoly villages switch to the incumbent. In summary, if the regulator reduces the incumbent's quality, then there is a reduction of product differentiation that increases competition. However, this effect is not enough to enhance the situation of consumers, because the entrant can still reduce its coverage.

The next simulation exercise analyzes the effects of increasing the entrant's quality level. As stated by Cremer et al. (1997), the imposition of a minimum quality standard is "the most natural instrument to achieve an increase in average quality".[15] The reason for this result is that a minimum quality level increases both the low and high quality levels.

[13] When $K = 1$, the private duopolists will establish the same qualities as in Cremer and Thisse (1994).

[14] The result that the two firms obtain the same profit when they have the same coverage is consistent with Moorthy (1988), for the case where firms choose products simultaneously, and with Cremer et al. (1997). This situation is a consequence of the linear and uniformly distributed preferences of the model, and the imposition of complete market participation.

[15] Ronnen (1991), Crampes and Hollander (1994), and Valletti (2000) also analyze the minimum quality standards.

Table 1
Simulation ($c = 0$, 1, and $\underline{\theta} = 2,5$)

	Total consumer surplus	Average consumer surplus			Π_1	Π_2	$\bar{\theta} - \tilde{\theta}$	μ_2	$x_1 - x_2$
		Incumbent's duopoly area	Entrant's duopoly area	Incumbent's monopoly area					
Unregulated market	25.25	0.362	0.230	0.214	7.65	7.65	0.29	0.70	21.43
$\Delta x_1 = -10\%$	22.08	0.326	0.205	0.192	13.35	5.64	0.31	0.57	20.74
$\Delta x_2 = 10\%$	26.03	0.389	0.247	0.217	6.35	8.30	0.23	0.69	20.21
$\Delta \mu_2 = 10\%$	29.19	0.394	0.251	0.266	6.31	6.31	0.35	0.77	19.47

Note 1. The profits of firms do not reflect their coverage costs.
Note 2. It is assumed that $F(\mu_2)$ is so large that the coverage level that would choose the entrant is always lower than the coverage that guarantees the affordability of the service by all consumers. As a result the entrant chooses a coverage such that $\underline{\theta} x_1 - p_1 = 0$.

Result 2. A 10% increase in the entrant's quality above x_2^e leads to a smaller increase in the incumbent's quality and, as a result, product differentiation decreases. Compared to the unregulated case, the incumbent's and the entrant's consumers are better off. In spite of this consumer welfare increase, the entrant reduces its coverage.

When the regulator establishes a minimum quality level, a reduction in product differentiation occurs that in turn produces cuts in prices if quality costs are not high. As a consequence, more consumers of the duopoly area choose the entrant. Moreover, the entrant compensates for the reduction in the product differentiation by reducing its coverage, since this strategy induces the incumbent to set a higher uniform price. Am effect of this strategy is that some consumers who were initially served by the entrant end up being served by the incumbent.

Next, I consider the possibility of regulating the entrant's area of coverage. Traditionally, regulators have required the incumbent postal operator to serve non-profitable villages. This regulation, together with the obligation to set a uniform price, implies that the incumbent will subsidize the loss-making regions with revenues obtained from the profitable regions. However, we have seen that this regulation also benefits entrants, since they can set higher prices if their coverage is narrower than that of the incumbent. Next, I show that the imposition of a minimum coverage level on the entrant can alleviate this situation. The fourth line of Table 1 shows that an increase of 10% in the entrant's coverage increases the consumers' surplus.

Result 3. A 10% increase in the entrant's coverage reduces the quality differentiation between firms. Compared to the unregulated case, consumers pay a lower price. Some consumers who were previously in the monopoly region are now served by the entrant and might be better off. Some consumers previously served by the entrant in the duopoly region are now served by the incumbent (see Appendix).

The imposition of a minimum coverage area on the entrant reduces the difference in coverage (i.e. increases the size of the duopoly region) and, as a consequence, reduces product differentiation. These changes strengthen competition and reduce the prices of both firms.

6. Mixed duopoly

The objective of this section is to extend the model of Section 4 to analyze the case in which the incumbent is a public firm that offers the higher quality service and covers all villages. To this end, I now consider that the incumbent's objective function is the sum of the consumer surplus and the profits of the two firms.

$$W = \mu_2 \left[\int_{\tilde{\theta}}^{\bar{\theta}} (\theta x_1 - p_1) \mathrm{d}\theta + \int_{\underline{\theta}}^{\tilde{\theta}} (\theta x_2 - p_2) \mathrm{d}\theta \right] + (1 - \mu_2) \int_{\underline{\theta}}^{\bar{\theta}} (\theta x_1 - p_1) d\theta + \Pi_1 + \Pi_2, \tag{18}$$

where $\tilde{\theta} = \frac{p_1 - p_2}{x_1 - x_2}$. I assume that the profit functions of the firms are the same as in Eqs. (6) and (7). The next proposition describes the firm's equilibrium allocations.

Proposition 6. *A mixed duopoly where the incumbent is a public firm that supplies the higher quality service offers the following equilibrium qualities:*

$$x_1 = \frac{8\underline{\theta} + 9K - 3(9K^2 - 8K)^{\frac{1}{2}}}{8c};$$
$$x_2 = \frac{8\underline{\theta} + 3K - (9K^2 - 8K)^{\frac{1}{2}}}{8c}. \tag{19}$$

With these qualities, if f(μ2) is sufficiently small, then the entrant covers the entire market, $\mu_2 = 1$.

An interesting result of this proposition is that in a mixed duopoly, firms choose the optimal quality allocations.[16] The private firm's incentive to offer the optimal allocation is that the pricing behavior of the public firm is more aggressive than that of a private competitor. As a consequence, the private firm is less interested in increasing product differentiation and delivers a higher quality service in order to increase its market share. The fact that the two firms choose exactly the optimal quality allocations is a consequence of our assumption that demand is inelastic.

The proposition considers the case in which the incumbent does not take into account its budget constraint, but it would be straightforward to include this restriction in our model. In a similar framework, Cremer et al. (1997) show that when a public firm considers its break-even constraint, the two firms set inefficient quality levels. The smaller the compensation owing to the public firm to reduce its deficit, the closer qualities are to their respective optimal levels. In this case, it is still possible to increase welfare by regulating qualities and coverage levels.

[16] Cremer et al. (1997) analyze this result in detail in a similar model.

Finally, the proposition shows that under a mixed duopoly, the entrant no longer has an incentive to establish a smaller coverage area than the incumbent in order to increase its uniform price. Although a smaller coverage area increases product differentiation, this reduction is not enough to compensate for the loss of market share. Note that in the case where $f(\mu_2)$ is sufficiently small, the entrant might even cover the entire market.

This result has important consequences for regulatory policy. It implies that the presence of a public firm alone neutralizes the strategic interest of the entrant in manipulating coverage to weaken competition. A public firm reduces prices and brings about optimal quality allocations. In addition, its presence creates the conditions that favors broader coverage by the entrant.

7. Competition with network externalities

This section extends the model of Section 2 in order to consider network externalities. To analyze the effect of network externalities on the decision of firms, I now assume that consumers are able to send letters to any village covered by the firm, and that the delivery of a letter outside its own village does not generate any additional costs. In addition, I assume that firms only provide end-to-end services. This assumption implies that a firm cannot ask its rival to deliver a letter it has collected.[17]

I assume that senders value both the quality of the service and the size of the firm's network. Calling b the magnitude of network externalities, a sender with type $\widetilde{\theta}$, located in one village of the duopoly region is indifferent between the incumbent and the entrant when:

$$\widetilde{\theta}x_1 + b - p_1 = \widetilde{\theta}x_2 + b\mu_2 - p_2, \tag{20}$$

where I have considered that $\mu_1 = 1$. With the full participation of senders, the incumbent's demand in the duopoly region is:

$$\overline{\theta} - \widetilde{\theta} = \overline{\theta} - \frac{p_1 - p_2 + b(\mu_2 - 1)}{x_1 - x_2}. \tag{21}$$

Taking this equation into account, the entrant's demand is $\widetilde{\theta} - \underline{\theta}$. Note that in this extended model, the entrant's demand increases with its relative coverage. Taking this situation into account, I can show that the profit-maximizing qualities of a private duopoly are as follows:

$$x_1^n = \frac{4\underline{\theta} + 5K}{4c} - \frac{2b(K-1)\mu_2}{3K};$$
$$x_2^n = \frac{4\underline{\theta} - K}{4c} - \frac{2b(K-1)\mu_2}{3K}. \tag{22}$$

Note that for any K, product differentiation is independent of the level of network externalities. However, when $K > 1$, network externalities reduce the quality levels offered by the two firms. In effect, coverage is now a quality attribute and the firms use it as a substitute for the intrinsic quality.

The next proposition analyzes how firms choose their coverage:

Proposition 7. *If b is small, then the entrant fixes the minimum coverage level that guarantees affordability of the service by all consumers. This action implies that $K > (4\underline{\theta})/7$. If b is sufficiently large, then the entrant prefers wider coverage and makes its coverage level closer to that of the incumbent.*

Network externalities offer consumers an additional utility source and as a consequence, the incumbent can set a higher price than would be possible in their absence. With network externalities, the entrant can reduce its coverage by more to increase the incumbent's price. In spite of this reduction, if the network externalities are sufficiently important, then the entrant will prefer to increase its coverage in order to obtain more clients rather than to reduce its coverage in order to increase the incumbent's uniform price. In this case, the entrant covers a larger proportion of the villages.

8. Conclusion

This paper has analyzed a duopoly in the postal sector in which firms determine their quality and coverage levels. In accordance with the previous literature, I showed that when the incumbent sets a uniform price, the entrant strategically chooses a lower coverage level than the incumbent in order to enlarge the incumbent's monopoly region and force an increase in the incumbent's service prices. In addition, I explain that firms take advantage of coverage differences to increase product differentiation. As a result, the entrant can obtain the same increase in prices with a smaller reduction in coverage.

The analysis of the interaction between coverage and quality is useful for understanding the implications of the universal service obligations (USOs) currently applied in the postal sector. The USOs are designed to guarantee a standard service at a uniform and affordable price. Traditionally, it has been thought that the entry of new operators into the low-cost regions reduces the incumbent's profitability and may force it to reduce the quality of its mail. The European Union has faced this problem by granting some reserved services to incumbent postal operators until 2009.

Some authors have suggested alternative mechanisms for financing the USOs. Armstrong (2001) proposes the creation of a USO fund financed by the entrants by means of a tax.[18] Crew and Kleindorfer (1998) suggest alleviating the cost of the USOs by re-examining the role of service standards. "For example, outlying areas might receive service three days a week instead of the typical five or six currently. In other areas, Saturday service might be eliminated. In the United Kingdom, twice daily deliveries might be eliminated in most areas. Another variable to consider might be to slow delivery. For example, in the case of First

[17] This is the present situation in many European countries such as Spain and the Netherlands. Indeed, in the EU, very few countries regulate the access to the incumbent's delivery network. See Footnote 4.

[18] Rodriguez and Storer (2000) study different approaches to estimating the cost of the USOs. In addition, Chone et al. (2000) and Anton et al. (1998) analyze different mechanisms to fund the USOs.

Class post in the United Kingdom, instead of providing service on the next day, First Class service would be redefined for outgoing areas to mean service on the second business day."

The main contribution of this paper has been to show that when governments establish universal service obligations entrants might strategically choose a lower coverage level or increase product differentiation in order to weaken competition. In addition, we have shown that in order to avoid this conduct, postal authorities could impose minimum coverage and quality requirements on the firms. However, it is important to be aware that these mechanisms might worsen the situation of some groups of consumers.

My results may be useful in orienting regulatory policy in the postal sector. In the last few years, national regulatory authorities have given considerable autonomy to incumbent public operators in order to enhance their commercial activity and to incentivize productive efficiency. In this context, as we have seen, a profit-oriented incumbent might choose pricing and quality decisions that reduce welfare, but these distortions could be prevented through the use of several regulatory instruments.

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Appendix

Proof of Proposition 1. By maximizing W with respect to $\widetilde{\theta}$, I obtain the optimal marginal consumer in each village $\mu \in [0,\mu_2]$, $\widetilde{\theta} = \frac{c(x_1+x_2)}{2}$. Substituting this expression into the welfare function in (3) and maximising with respect to the two quality levels I obtained the following first-order conditions:

$$-\frac{1}{2}\underline{\theta}^2 + \frac{1}{2}\left(\frac{c(x_1+x_2)}{2}\right)^2 = cx_2\frac{c(x_1+x_2)}{2} - cx_2\underline{\theta}; \tag{23}$$

$$-\frac{1}{2}\underline{\theta}^2 + \frac{1}{2}\left(\frac{c(x_1+x_2)}{2}\right)^2 = cx_1\frac{c(x_1+x_2)}{2} - cx_1\underline{\theta} + \frac{1}{\mu_2}\left[\left(\frac{1}{2}\overline{\theta}^2 - cX_1\overline{\theta}\right) - \left(\frac{1}{2}\underline{\theta}^2 - cx_1\underline{\theta}\right)\right]. \tag{24}$$

Defining $K = \frac{\mu_1}{\mu_2}$ and solving I obtain the first part of the proportion. Finally, by substituting the optimal qualities into the welfare function and differentiating with respect to μ_2, we obtain the entrant's optimal coverage. □

Proof of Proposition 2. From (8) and (9) I obtain:

$$\frac{\partial p_1}{\partial x_1} = \frac{1}{3}[(2\overline{\theta} - \underline{\theta}) + 2cx_1 + +2(K-1)] > 0; \tag{25}$$

$$\frac{\partial p_1}{\partial x_2} = \frac{1}{3}[-(2\overline{\theta} - \underline{\theta}) - cx_2 + -2(K-1)]; \tag{26}$$

$$\frac{\partial p_2}{\partial x_2} = \frac{1}{3}[-(\overline{\theta} - 2\underline{\theta}) + 2cx_2 - (K-1)]; \tag{27}$$

$$\frac{\partial p_2}{\partial x_1} = \frac{1}{3}[(\overline{\theta} - 2\underline{\theta}) + cx_1 + (K-1)] > 0. \tag{28}$$

When the entrant's marginal cost of quality ($c\,x_2$) is sufficiently small, then $\frac{\partial p_1}{\partial x_2}, \frac{\partial p_2}{\partial x_2} < 0$.

In order to analyze how the modification of qualities affects the firms profits, observe the following results:

$$\frac{d\Pi_2}{dx_1} = \frac{\partial \Pi_2}{\partial p_1}\frac{\partial p_1}{\partial x_1} > 0; \quad \frac{d\Pi_2}{dx_2} = \frac{\partial \Pi_2}{\partial p_1}\frac{\partial p_1}{\partial x_2} < 0; \tag{29}$$

$$\frac{d\pi_1^m}{dx_1} = \frac{\partial \Pi_1^m}{\partial p_1}\frac{\partial p_1}{\partial x_1} > 0; \quad \frac{d\pi_1^m}{dx_2} = \frac{\partial \Pi_1^m}{\partial p_1}\frac{\partial p_1}{\partial x_2} < 0, \tag{30}$$

$$\frac{d\pi_1^d}{dx_1} = \frac{\partial \Pi_1^d}{\partial p_1}\frac{\partial p_1}{\partial x_1} + \frac{\partial \Pi_1^d}{\partial p_2}\frac{\partial p_2}{\partial x_1}; \tag{31}$$

$$\frac{d\pi_1^d}{dx_2} = \frac{\partial \Pi_1^d}{\partial p_1}\frac{\partial p_1}{\partial x_2} + \frac{\partial \Pi_1^d}{\partial p_2}\frac{\partial p_2}{\partial x_2}. \tag{32}$$

The signs of Eqs. (30) and (31) depend on the entrant's level of coverage. First, observe that $\frac{\partial p_1}{\partial x_1} > \frac{\partial p_2}{\partial x_1}$. Taking into account that $\frac{\partial \pi_1^d}{\partial p_1} < 0$, if $\frac{\partial \pi_1^d}{\partial p_1} > \frac{\partial \pi_1^d}{\partial p_2}$ we have that $\frac{d\pi_1^d}{dx_1} < 0$. However, when the duopoly area is large, it may be that the second term in the right hand-side of Eq. (30) is bigger than the first since the price is closer to the price that will establish a duopolist. In this case, $\frac{d\pi_1^d}{dp_1} < 0$ is small. As a result, an increase in x_1 may generate an increase in the profit of the incumbent. For the same reason, an increase of x_2 may generate a decrease in the incumbent's profit. □

Proof of Proposition 3. Eq. (11) defines the qualities of the firms when the incumbent provides high quality service. From these qualities, we obtain the effect of increasing the level of relative coverage:

$$\frac{d(x_1 - x_2)}{dK} = \frac{3}{2c}. \tag{33}$$

In addition, the qualities when the entrant provides high quality service are:

$$x_2 = \frac{4\underline{\theta} + 4 + K}{4c}; \quad x_1 = \frac{4\underline{\theta} + 4 - 5K}{4c}. \tag{34}$$

In this case, the effect of a variation in the level of relative coverage satisfies:

$$\frac{d(x_2 - x_1)}{dK} = \frac{3}{2c} > 0. \quad \square \tag{35}$$

Proof of Proposition 4. Consider the incumbent's profit function. The first and second order conditions are:

$$\frac{(2\overline{\theta} - \underline{\theta})}{2} - cx_1 + K - 1 - \frac{c}{4}\frac{(x_2^2 - x_1^2)}{(x_1 - x_2)} = 0; \tag{36}$$

$$-\frac{3c}{4} < 0. \tag{37}$$

Taking these conditions into account one can write d x_1/d $x_2 = -(c/4)/(-3c/4) > 0$. From the entrant's profit function I obtain the first and second order conditions:

$$-\frac{(\overline{\theta}-2\underline{\theta})}{2}-cx_2-\frac{(K-1)}{2}+\frac{c}{4}\frac{(x_1^2-x_2^2)}{(x_1-x_2)}=0; \tag{38}$$

$$-\frac{3c}{4}<0. \tag{39}$$

From these, I obtain $d\,x_2/d\,x_1 = -(c/4)/(-3c/4) > 0$. Therefore, the duopolists react less than proportionately to an increase in the quality of their rivals. □

Proof of Proposition 5. The first order conditions of Π_2 with respect to μ_2 are always negative. The result of the proposition is obtained by considering that $K = \frac{4\theta}{7}$. Observe that in this case, we obtain that $\underline{\theta}x_1 - p_1 = 0$. □

Proof of Result 3 An increase in μ_2 decreases the level of relative coverage.

$$\frac{dK}{d\mu_2}=\frac{1}{\mu_2}\left(\frac{d\mu_1}{d\mu_2}-K\right)<0. \tag{40}$$

The indifferent consumer can be defined as

$$\widetilde{\theta}=\frac{p_1-p_2}{x_1-x_2}=\frac{1}{3}\left[(\overline{\theta}+\underline{\theta})+\frac{c}{2}(x_1+x_2)+(K-1)\right]=\underline{\theta}+\frac{K}{2}. \tag{41}$$

Therefore, a reduction in K reduces the preference for quality of the indifferent consumer.

Proof of Proposition 6. From Eq. (18), the solution of the first order conditions of the firms yields the following prices:

$$\begin{aligned} p_1&=\underline{\theta}(x_2-x_1)+\frac{c}{2}(2x_1^2-x_2^2);\\ p_2&=\underline{\theta}(x_2-x_1)+\frac{c}{2}x_1^2. \end{aligned} \tag{42}$$

Substituting these prices into the objective functions of the firms and deriving with respect to the qualities we obtain the quality levels of the proposition. Next, I substitute the equilibrium qualities into the entrant's profit function to obtain:

$$\Pi_2=27-18\mu_2+\left(\frac{9-8\mu_2}{\mu_2^2}\right)^{\frac{1}{2}}\mu_2(2\mu_2-9)-F(\mu_2). \tag{43}$$

Deriving with respect to μ_2 yields:

$$\frac{\partial\Pi_2}{\partial\mu_2}=\frac{3[81+8(\mu_2-9)\mu_2]-\mu_2\left(\frac{9-8\mu_2}{\mu_2^2}\right)^{\frac{1}{2}}(81-36\mu_2)}{16c\left(\frac{9-8\mu_2}{\mu_2^2}\right)^{\frac{1}{2}}\mu_2^5}-f(\mu_2). \tag{44}$$

Note that when $f(\mu_2)$ is sufficiently small, this derivative is always positive. □

Proof of Proposition 7. With network externalities the incumbent's price is:

$$\begin{aligned} p_1=\frac{1}{3}\Big[&(x_1-x_2)(2\overline{\theta}-\underline{\theta})+cx_1^2+\frac{c}{2}x_2^2\\ &+(K-1)(b\mu_2+2(x_1-x_2))\Big]. \end{aligned} \tag{45}$$

Therefore, the entrant's profit is:

$$\Pi_2=\frac{\mu_2 3K}{9c2}\left(\frac{3K}{2}+\frac{b(K-1)\mu_2(4-3K)}{3K}\right)^2-F(\mu_2). \tag{46}$$

Differentiating this expression with respect to μ_2 shows that for a large b, the entrant sets $\mu_2 > \frac{7}{4\underline{\theta}}$, which implies that $K < \frac{4\underline{\theta}}{7}$. □

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