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ORIGINAL ARTICLE

Access charges under two-tier pricing

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Abstract This article analyzes the regulation of access charges in a liberalized postal market where operators use two-tier pricing. It develops a model of vertical product differentiation that allows determination of the demand for First and Second Class mail from an incumbent postal operator and a group of entrants. The optimal access charges for First and Second Class letters are determined as well as the optimal quality for these services.

Keywords Postal market · Two-tier pricing · Access pricing · Quality

JEL Classifications D43 · L51 · L97

1 Introduction

Postal operators usually segment the market by offering First and Second Class mail. First Class receives priority treatment and quicker delivery than Second Class mail. The implication is that First Class will be sorted overnight, thus incurring a labor premium. By contrast, Second Class letters have a lower service guarantee, allowing operators to smooth the processing and reduce average costs. This cost saving is reflected at least in part in the price differential between First and Second Class mail. This pricing strategy is known as two-tier pricing and was first introduced by the

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British Post Office in 1968.[1] In recent years, the liberalization and automation of the postal industry have affected the way operators use two-tier pricing. One key policy of such liberalization is to allow entrants to use parts of the network of the incumbent Postal Operator (PO) to deliver their mail. Entrants then take into account the price and quality of the access services when considering this option. This paper studies the optimal access policy under two-tier pricing.

The first contribution of this paper is to analyze a model where operators use two-tier pricing and are able to determine the quality of service for particular letters. Crew et al. (1990, 1997) demonstrated that two-tier pricing is related to the mainstream theory of peak-load pricing. The authors show that when postal firms establish different prices for First and Second Class letters they ameliorate sorting issues and reduce the peak problem.[2] "Because mail service prices cannot vary with time of day but only with class, it is not possible to charge prices equal to the time-varying marginal costs. Instead prices are uniform over time but vary with class. Prices for each class are related to marginal costs".[3] The present paper follows this idea and recognizes that operators offer services with different qualities to address the peak-load problem. However, in contrast to these authors, it is assumed that operators endogenously determine the quality of letters. Indeed postal operators use sophisticated processing technologies to differentiate their services and attract specific groups of mailers. In this situation, entry affects the demand experienced by a PO for First and Second Class letters, the quality of the services offered, and the participation in the market. This paper incorporates the endogenous nature of quality by following the model of vertical product differentiation introduced by Mussa and Rosen (1978) and Moorthy (1988), which was adapted to the specific features of the postal sector by Cremer et al. (1997).

The second contribution of the paper is to consider the notion that the PO can offer access services of different qualities. Research on worksharing discounts and access charges in the postal sector has traditionally ignored the quality of retail and wholesale services.[4] Crew and Kleindorfer (1991); Sherman (2001); Billette de Villemeur et al. (2003) and Calzada (2006) identify the optimal worksharing discounts when a group of mailers pre-sort their mail. Billette de Villemeur et al. (2004) characterize the optimal access policy when there is one incumbent PO and one entrant delivering single-piece and bulk mail at low and high cost areas, and delivery of single-piece letters is offered by the PO at one uniform price. Panzar (2003) and Billette de Villemeur et al. (2005) study the worksharing and access problem simultaneously when the entrants seek access in only one delivery area.

[1] The original insight on the labour premium charged to First Class mail is due to Panzar (1984), in a testimony presented to the U.S. Postal Rate Commission. For a detailed analysis of the two-tier system in UK see Crew et al. (1990) and Crew and Kleindorfer (2002).

[2] Crew and Kleindorfer (1991, 1992) examine Ramsey optimal peak-load pricing. Crew and Kleindorfer (2002) examine the relationship between the mark-ups for First and Second Class mail under competition and under varying levels of Universal Service Obligation (USO). They conclude that a two-tier system mitigates the effects of the break-even and USO constraints on the PO.

[3] Crew et al. (1990).

[4] A detailed analysis of the access problem in the telecommunications sector can be found in Laffont and Tirole (1996, 2000), Armstrong (2002); Vogelsang (2003) and Peitz et al. (2004).

De Donder (2006) analyzes the access problem when one PO offers access to both competitors and customers, the competitors can bypass the PO, and the PO is required to satisfy some universal service obligations (USO). He shows how a geographically uniform pricing constraint on the PO distorts the access charges. Crew and Kleindorfer (2002) study an access system where entrants pay different charges that depend on the final destination of the mail. They show that this system is more efficient than uniform access pricing and mitigates the problems for financing the USO.

One common feature of this literature is that it assumes that operators only offer one class of mail of a pre-determined quality. One objective of this paper, by contrast, is to analyze the access policy when operators are able to set the quality of letters. I develop a model where one regulator establishes the PO's retail prices, the access charges, as well as the quality of the access services. As has been shown in the previous literature, the welfare-maximizing access charges are based on the direct cost of access plus the PO's opportunity cost for delivering the letters of the entrants and a positive Ramsey term. With two-tier pricing, however, the access charge for each class of mail also depends on the quality of the letters to be distributed by the PO.[5] Bearing this in mind, the objective of the regulator is to establish the quality of wholesale and retail services that maximize social welfare.[6]

The quality of access services is a relevant and realistic problem that affects the evolution of competition in the postal sector. Some recent experiences show that the incumbent PO may try to negotiate high access charges, arguing that it is the First Class rate and costs that should set the standard for any discounts for access. POs argue that once entrant mail and PO generated mail are commingled at the delivery point, everything becomes First Class. By contrast, entrants emphasize that the Second Class mail price and cost should be the standard, since they are providing most of the upstream work where the purported savings in peak costs are incurred.

The remainder of the paper is structured as follows. Section 2 describes the peak-load problem in the postal sector and how it is affected by the modernization of the industry. Section 3 presents a model of access when an incumbent PO and a fringe of price-taking entrants offer differentiated services. Finally, Section 4 summarizes the main results.

2 Two-tier pricing in the postal sector

In the postal sector, the peak-load problem has traditionally been less severe than in other network industries, such as electricity or telecommunications. In part, this is

[5] The model does not contemplate the possibility that the PO modifies the quality of access in order to raise its competitor's costs or to reduce its attractiveness. Instead, the PO offers its competitors the same delivery quality that it provides to himself. Sappington (2005) analyzes in a more general context the provision of wholesale service quality.

[6] Gal-Or (1983) considers an oligopoly where firms offer a stream of products of different qualities to segment the market and employ partial price discrimination. She shows that when an additional firm enters the industry competition is more intense and firms choose a product mix with a bigger percentage of low quality products. This allows firms to discriminate more effectively among consumers that value the product more highly.

due to the use of two-tier pricing. However, in recent years the introduction of new capital-intensive technologies has intensified the peak problem. Automation of sorting and other mail processing activities is changing the nature of the sector, making it more like other public utilities in their technological diversity.

Automation affects the PO's rates and costs in several ways: First, much of the mail is sorted in walk-sequence down to the level of the carrier's route, and the carrier need sort only a small fraction of the mail. This process enables the extension of routes and reductions in the number of carriers. However, it also increases the peak in demand for barcode sorting capacity. Second, industrial automation may simultaneously reduce costs and improve quality and reliability of postal services. Third, mailers and consolidators are more interested in bypassing segments of the PO system. This changes the points at which the PO receives mail for final delivery. Finally, as Crew and Kleindorfer (2002) suggest, automation equipment acts like a base-load technology in the peak-load problem, reducing flexibility and possibly increasing the price difference between First and Second Class mail.

The liberalization of the postal market also affects the two-tier pricing policy. In recent years, entry has particularly affected Second Class mail, and as a consequence, incumbent operators have modified their product line to defend this type of service. Taking this into account, regulators should be aware of the effects on competition of pricing and quality standards for access charges. For example, there are some concerns that the delivery of unsorted mail by entrants at the Delivery Offices would compromise the achievement of further economies of scale in the sorting stage in other parts of the network.

The regulation of access influences the entry strategy of new operators. In Sweden, CityMail, which began operations in 1991, has not reached an agreement with the incumbent operator to determine worksharing discounts. It offers end-to-end services, delivering three days a week, instead of the five days provided by the incumbent.[7] This reduces costs and attracts a portion of non-priority letter business. Similarly, in the Netherlands the main competitor to the incumbent operator provides direct mail services with nation-wide delivery twice a week.

In the United States, two-tier pricing is employed indirectly and incompletely. Preferred mail is given priority handling and does arrive much more quickly than non-preferred, in part because, in the US, distance is very important. Non-preferred mail consists primarily of advertising material, books, parcels and the like. This service is not available to individuals, and for this reason the US pricing system is considered an incomplete form of peak-load pricing.

The US market has not been liberalized, but since 1976 there have been worksharing discounts that allow efficient mailers and consolidators to carry out part of the sorting before delivering their correspondence to the USPS. Worksharing products by entrants are imperfect substitutes for USPS products, and this has led to very large demand

[7] Jonsson and Selander (2005) and Cohen et al. (2005, 2007) analyze the liberalization in Sweden. ECORYS (2005) shows that Sweden regulates access to PO boxes and that there is negotiated access to sorting centers. On the other hand, through mediation by the National Post and Telecom Agency, the prices for CityMail's access to post office boxes and for the forwarding of CityMail's undeliverable (as addressed) mail have been agreed upon.

increases.[8] In the U.S., discounts depend on the degree of sorting provided and on the element of USPS's network to which the correspondence is delivered. Many mailers use these worksharing options because the deeper into the sorting network mail is drop-shipped, the faster it is delivered.

In France, the upstream market has been open to competition since the 1960s and mail consolidation has developed rather strongly, with mailers having three points of upstream and downstream access for final delivery by La Poste. There is negotiated access to sorting centers at national, department and postal code levels. La Poste's main competitor in direct and unaddressed mail is Adrexo. This firm focuses on the last mile of delivery and has almost complete territorial coverage. It delivers at least three times per week in urban areas and one to two times per week in rural areas.

Worksharing between La Poste and consolidators and large consumers can take three different forms. The "product-based" contract covers direct mail, parcels and transactions mail, specifying the general access conditions and service quality standards for the products and the discounts for each level of worksharing. The "technical contract" covers specific additional matters such as time windows to tender mail or additional refinements in sortation. Finally, "commercial contracts" specify periodic rebates based on total volumes provided by a commercial client.[9]

Finally, in the United Kingdom liberalization has been promoted through the regulation of access. Entrants in the upstream activities use the distribution network of Royal Mail for final delivery. On the other hand, operators offering full end-to-end services can use the network of Royal Mail to reach some high cost regions. Some operators have negotiated with the incumbent to establish the conditions for downstream access. UK Mail entered the market after reaching an access agreement with Royal Mail. This firm collects Second Class mail from customers and passes all mail to Royal Mail at the Inward Mail Center for final delivery. Royal Mail then must provide a next-day delivery service. This business strategy allows UK Mail to provide extensive tracking and tracing until the mail is handed over to Royal Mail, a level of certainty that might attract mailers that require time-certain delivery.

In February 2004, after two years of negotiations, Royal Mail and UK Mail avoided a regulatory determination and agreed on the terms of access.[10] Subsequently, Royal Mail reached agreements with TPG and Deutsche Post. Royal Mail and UK Mail agreed on weight based access charges for mail injected at Royal Mail's Inward Mail Centers (IMC). The agreement considers prices for items sorted to either 120 outward postcode selections or around 1.400 delivery office selections. However, no price has been agreed for Delivery Office access, which was the original goal of UK Mail.

[8] Cohen et al. (2001, 2006) demonstrate that the introduction of discounts initiated significant growth in the demand for mail.

[9] See PricewaterhouseCoopers (2006).

[10] See Postcomm (2004) for a detailed description of the access negotiation.

3 The model

Imagine a postal market where the regulator determines the retail prices of an incumbent PO and the access charges that a fringe of price-taking entrants pay to the PO to use its delivery network. The Postal Operator ($i = \text{PO}$) collects and sorts the mail of a group of senders and delivers their letters throughout the country. The fringe ($i = \text{E}$) collects and sorts the mail of all other senders, but uses the PO's network to deliver the letters. In order to simplify the model, assume that the fringe delivers all its letters to one access point, for example the PO's Outward Sortation facilities.

The quality of letters has two dimensions. The first component shows the difference between First ($j = 1$) and Second Class ($j = 2$) letters, and is independent of the type of operator. This dimension of quality is represented by x_j, and it could reflect, for example, the speed of sorting at the delivery offices and delivery of mail. I assume that the quality of First Class delivery is higher than that of Second Class, $x_1 \geq x_2$.

The second component of quality shows the ability of the PO and the fringe to offer differentiated services, and is independent of the class of delivery produced. I denote this type of quality by y^i. This could reflect the speed of collection and sorting at the Outward Sortation facility, or the reliability of the service, which can be monitored through mechanisms such as tracking and tracing. In order to simplify the model, I normalize the quality of the fringe and assume that the PO offers a higher quality, $y^E = 0$ and $y^{PO} > 0$. Finally, consider that the sender's perceived quality is the sum of the quality offered by the class of letter and by the operator, $z_j^i = x_j + y^i$.

In order to represent a market with vertical product differentiation it is useful to follow the model of Mussa and Rosen (1978), which was adapted to the postal sector by Cremer et al. (1997). Assume that senders have quasi-linear preferences so that the marginal utility of income is constant and is the same for all consumers. Each sender has a preference θ for quality and senders are uniformly distributed in the support $\theta \in \left[\underline{\theta}, \bar{\theta}\right]$. Senders have a perfectly inelastic demand that is normalized to one.

The net surplus of a sender with type θ who sends one letter of quality z_j^i at price p_j^i is given by $\theta z_j^i - p_j^i$. Taking this into account, it is possible to define the operator's demands. The PO's demand of First and Second Class letters are:

$$q_1^{PO}\left(p_1^E, z_1^E, p_1^{PO}, z_1^{PO}\right) = \bar{\theta} - \theta_4 = \bar{\theta} - \frac{p_1^E - p_1^{PO}}{z_1^E - z_1^{PO}}; \tag{1}$$

$$q_2^{PO}\left(p_1^E, z_1^E, p_2^{PO}, z_2^{PO}, p_2^E, z_2^E\right) = \theta_3 - \theta_2 = \frac{p_2^{PO} - p_1^E}{z_2^{PO} - z_1^E} - \frac{p_2^E - p_2^{PO}}{z_2^E - z_2^{PO}}, \tag{2}$$

where $\theta_4 = \theta_4\left(p_1^E, z_1^E, p_1^{PO}, z_1^{PO}\right)$ is the pivotal sender, who is indifferent in the choice between First Class letter service from the PO and that from the fringe. $\theta_3 = \theta_3\left(p_2^{PO}, z_2^{PO}, p_1^E, z_1^E\right)$ is the sender who is indifferent between the PO's Second Class and the fringe's First Class letters. $\theta_2 = \theta_2\left(p_2^E, z_2^E, p_2^{PO}, z_2^{PO}\right)$ is the sender

indifferent when choosing between Second Class letters from the PO and the fringe. I assume that the demands of the two operators are always positive.[11]

The fringe's demand of First and Second Class letters are:

$$q_1^E\left(p_1^E, z_1^E, p_1^{PO}, z_1^{PO}, p_2^{PO}, z_2^{PO}\right) = \theta_4 - \theta_3 = \frac{p_1^E - p_1^{PO}}{z_1^E - z_1^{PO}} - \frac{p_2^{PO} - p_1^E}{z_2^{PO} - z_1^E}; \quad (3)$$

$$q_2^E\left(p_2^E, z_2^E, p_2^{PO}, z_2^{PO}\right) = \theta_2 - \theta_1 = \frac{p_2^E - p_2^{PO}}{z_2^E - z_2^{PO}} - \frac{p_2^E}{z_2^E}, \quad (4)$$

where $\theta_1 = \theta_1\left(p_2^E, z_2^E\right)$ is the sender who is indifferent between buying Second Class letter service from the fringe and not buying anything. I impose the condition that $\theta_1 > \underline{\theta}$, and therefore the analysis is restricted to the case where there is partial participation in the market. This implies that the fringe's price of Second Class letters is so high, and/or its quality so low, that senders with low value mail might prefer to stay out of the market.

The postal value chain for letters consists of collection, sorting and delivery. I call c_1 the marginal cost of collection, which is the same for the PO and the fringe, and c_2 the PO's marginal cost of delivery. I call $c = c_1 + c_2$ the joint cost of collection and delivery. Finally, consider that the PO's cost of sorting the mail of the fringe is sx_j^2, while the cost of sorting its own mail is $s(x_j + y^{PO})^2$. This cost structure reflects the additional cost of supplying a service of higher quality. An increase in the speed of delivery requires a greater expenditure of resources in the sorting stage. Taking this into account, Second Class letters are sorted during regular working hours, while First Class letters are sorted at night at an extra cost. Finally, assume that only the PO faces Universal Service Obligations (USO), which are represented by the fixed cost F.

3.1 The monopoly benchmark

Before analyzing the optimal access policy under two-tier pricing it is useful to identify the retail prices and quality levels that would be provided by a regulated and an unregulated monopoly. The profit function of an unregulated PO that offers First and Second Class letters is

$$\Pi^{PO} = \left(p_1 - c - sx_1^2\right) q_1^{\mathrm{PO}} + \left(p_2 - c - sx_2^2\right) q_2^{\mathrm{PO}} - F, \quad (5)$$

where $q_1^{PO} = q_1^{PO}(p_1, x_1, p_2, x_2) = \overline{\theta} - \tilde{\theta}$ and $q_2^{PO} = q_2^{PO}(p_1, x_1, p_2, x_2) = \tilde{\theta} - \theta_0$ are the demands of First and Second Class letters. In order to construct these demands, consider that $\tilde{\theta} = (p_1 - p_2)/(x_1 - x_2)$ is the sender that is just indifferent

[11] A complete determination of the payoff functions of operators must consider the cases where this is not satisfied, although this is beyond the objective of the present work. For this reason, I restrict to the case where $p_{12} < p_{21}$, which requires that $x_2 + y^{PO} < x_1$.

between sending First and Second Class letters, and $\theta_0 = p_2/x_2$ is the sender that is indifferent between sending a Second Class letter and not sending anything.

Consider also the case where one regulator sets the PO's prices and quality levels. The regulator maximizes the unweighted sum of the senders surplus and the PO's profit, subject to the constraint that the PO realizes non-negative profits, $\Pi^{PO} \geq 0$. The Lagrangian of this problem can be written as follows

$$W = \int_{\tilde{\theta}}^{\bar{\theta}} (\theta x_1 - p_1)\, d\theta + \int_{\theta_0}^{\tilde{\theta}} (\theta x_2 - p_2) d\theta + (1+\lambda)\, \Pi^{PO}, \tag{6}$$

where $\lambda \geq 0$ is the multiplier associated to the PO's budget constraint. The first two terms of this equation represent the aggregate surplus of the consumers that send First and Second Class letters. The third term shows the weighted profit of the PO.

Taking into account Eqs. 5 and 6, the next proposition compares the allocations generated by a regulasted and an unregulated PO when there is partial participation in the market (see Appendix).

Proposition 1 *Consider a monopoly PO that applies two-tier pricing. Given the qualities x_1 and x_2 , when $\lambda > 0$ the optimal Ramsey (r) prices for First and Second Class letters that maximize social welfare imply bracketing between the first best (fb) and the monopoly (m) prices, $p_i^{fb} < p_i^r < p_i^m$.*

$$\begin{aligned} p_1^{fb} = c + s x_1^2 < p_1^r = \frac{\left(c + s x_1^2\right)(1+\lambda) + x_1 \overline{\theta} \lambda}{1+2\lambda} < p_1^m = \frac{1}{2}\left[c + x_1\left(\overline{\theta} + s x_1\right)\right] \\ p_2^{fb} = c + s x_2^2 < p_2^r = \frac{\left(c + s x_2^2\right)(1+\lambda) + x_2 \overline{\theta} \lambda}{1+2\lambda} < p_2^m = \frac{1}{2}\left[c + x_2\left(\overline{\theta} + s x_2\right)\right] \end{aligned} \tag{7}$$

The regulator and the unregulated PO choose the same qualities for First and Second Class letters:

$$x_1^m = \frac{11\overline{\theta} + \left(\overline{\theta}^2 + 60sc\right)^{\frac{1}{2}}}{30s}; \quad x_2^m = \frac{\overline{\theta} + \left(\overline{\theta}^2 + 60sc\right)^{\frac{1}{2}}}{10s}. \tag{8}$$

The first part of the Proposition shows the profit and welfare-maximizing prices of First and Second Class letters.[12] When the PO's budget constraint is not binding, $\lambda = 0$, the regulator establishes the first best prices $p_i^{fb} = c + s x_i^2$. These prices only cover the variable costs and the PO makes a loss equal to F. If instead the PO's budget constraint is binding, $\lambda > 0$, the regulator establishes the Ramsey prices, which are greater than the first best prices.

[12] Note that when $c = 0$ this yields the same result than in Moorthy (1988).

The second part of the Proposition shows the qualities provided by the monopoly. Note that the regulator and an unregulated monopoly choose the same qualities for First and Second Class letters. In fact, these are the qualities that optimize participation in the market for any given level of prices. In spite of this, the regulator sets lower prices than an unregulated monopoly, which increases consumer participation.[13]

Finally, observe that when $\overline{\theta}$ increases the average willingness to pay for quality increases, and the qualities of the two classes of letters increase as well. By contrast, when s increases, the marginal cost of quality increases and the qualities of letters decrease. In this case, the difference in quality between First and Second Class letters, $x_1^m - x_2^m$ decreases if $4sc < \bar{\theta}^2$.

3.2 Access with product differentiation

This section examines the optimal regulation of the access charges. I consider that entrants collect and pre-sort the letters of some senders and afterwards deliver the letters in the PO's pipeline for final distribution. Entrants pay the PO an access charge, a_j, that is different for First and Second Class letters.

Consider a model with two stages. In the first, the regulator determines the common and private components of quality provided by the PO. The quality of mail is difficult to modify in the short run because any change requires investment and organizational adaptations. In the second stage, the regulator sets the access charges and the PO's retail prices simultaneously. As a consequence, the fringe's retail prices are determined as well. Finally, consumers choose their preferred operator and the Class of mail they consume. The model is solved by backward induction.

Given the previous characterization of the costs and demands of First and Second Class letters the profit of the fringe can be written as follows

$$\Pi^E = \sum_{j=1}^{2} \left(p_j^E - c_1 - a_j \right) q_j^E. \tag{9}$$

Notice that entrants act as a competitive fringe, and therefore $p_j^E = c_1 + a_j$. Moreover, the volume of letters supplied by the fringe is equal to its demand for access. Bearing this in mind, when $q_j^E > 0$ the profit function of the PO is given by

$$\Pi^{PO} = \sum_{j=1}^{2} \left(p_j^{PO} - c - s \left(z_j^{PO} \right)^2 \right) q_j^{PO} + \sum_{j=1}^{2} \left(a_j - c_2 - s x_j^2 \right) q_j^E - F. \tag{10}$$

The regulator establishes the PO's retail prices and the access charges that maximize a social welfare function. As before, consider that welfare is the unweighted sum of

[13] Moorthy (1988) shows that the equality between the qualities of a regulated and an unregulated monopoly do not obtain under full participation in the market. With partial participation, cannibalization minimization considerations must be trade off against increased competition with the substitute. If preferences are uniformly distributed, these two effects exact balance. In contrast, with full participation only the cannibalization minimization consideration applies.

the consumer surplus and industry profits. Moreover, assume that the PO must have non-negative profits, $\Pi^{PO} \geq 0$. Taking this into account, the regulator maximizes the following function:

$$W = \int_{\theta_4}^{\bar{\theta}} \left(\theta z_1^{PO} - p_1^{PO}\right) d\theta + \int_{\theta_3}^{\theta_4} \left(\theta x_1 - p_1^E\right) d\theta + \int_{\theta_2}^{\theta_3} \left(\theta z_2^{PO} - p_2^{PO}\right) d\theta + \int_{\theta_1}^{\theta_2} \left(\theta x_2 - p_2^E\right) d\theta + (1+\lambda)\,\Pi^{PO} + \Pi^E, \quad (11)$$

where $\lambda \geq 0$ is the Lagrange multiplier associated to the PO's break-even constraint. The first part of this Lagrangian represents the net surplus obtained by the four groups of senders. The first two groups of senders buy First Class letters and the second two groups, Second Class letters.

3.2.1 Optimal access policy

Next I analyze the structure of the optimal access charges established by the regulator. Afterwards, I completely determine the access charges and the PO's retail prices.

Proposition 2 *Consider a PO that applies two-tier pricing and offers access to a fringe of price-taking entrants. When operators offer differentiated services the optimal access charges satisfy:*

$$\underbrace{a_j = c_2 + s x_j^2}_{\text{Direct cost of sorting}} + \underbrace{\left[p_1^{PO} - c - s\left(z_1^{PO}\right)^2\right] \frac{-\partial q_1^{PO}/\partial a_j}{\partial q_j^E/\partial a_j} + \left[p_2^{PO} - c - s\left(z_2^{PO}\right)^2\right] \frac{-\partial q_2^{PO}/\partial a_j}{\partial q_j^E/\partial a_j}}_{\text{PO}'\text{s opportunity cost of access}} - \underbrace{\frac{\lambda}{1+\lambda} \frac{q_j^E}{\partial q_j^E/\partial a_j}}_{\text{Ramsey term}} \text{ for } j = 1, 2 \quad (12)$$

The structure of the access charges in (12) is similar to the optimal one-way access charges for the telecommunications sector identified by Laffont and Tirole (1996) and Armstrong et al. (1996), or to the optimal worksharing discounts and access charges in the postal sector identified by Sherman (2001), Billette de Villemeur et al. (2003, 2004), and De Donder (2006). In my model, however, firms use two-tier pricing and as a result I obtain the access charges for First and Second Class letters, which depend on quality levels.

The optimal charges of Eq. 12 are equal to the direct cost of sorting plus the PO's opportunity cost of giving access and a positive Ramsey term that reflects how the

access charge has to be increased in order to satisfy the PO's break-even constraint. The economic intuition behind the Ramsey term is that in order to finance the PO's fixed cost it is preferably to increase the price to those consumers less sensitive to price.

The PO's opportunity cost shows the PO's loss of profits in the retail market when it gives one unit of access to the fringe. With entry the PO losses revenues that are essential to finance its fixed costs and as a consequence it is compensated with an access charge that is higher than the direct cost of access. On the other hand, notice that entry into either First or Second Class mail has a different effect on the PO. As a result, the access charges for each class of mail are different.

Finally, note that in the PO's opportunity cost term, the marginal profits for First and Second Class letters are weighted by a term that represents the volume of letters lost by the PO, due to an increase in sales by the fringe, when there is a reduction of the access charge. The literature on access charges calls these weights displacement ratios, and in my model they are defined as $\sigma_{1j} = \left(\partial q_1^{PO}/\partial a_j\right) / \left(\partial q_j^E/\partial a_j\right)$ and $\sigma_{2j} = \left(\partial q_2^{PO}/\partial a_j\right) / \left(\partial q_j^E/\partial a_j\right)$. Note that when the PO and the entrants offer services that are perfect substitutes then $\sigma_{ii} = 1$ and $\sigma_{ij} = 0$. That is, when operators offer the same qualities a change in the access charge modifies the quantity of letters supplied by each operator, but not the total volume of First and Second Class mail.

The optimal access charges in Proposition 2 have two interesting features. First, the charges depend on the quality of the access services, which are established by the regulator to maximize welfare. Second, the charges consider the interdependencies between First and Second Class letters. When the access charge for First Class letters, a_1, is reduced, demand interdependencies imply that some senders who had been using the PO's Second Class letters now use the fringe's First Class service. For this reason, the PO's opportunity cost is the weighted average of the PO's marginal profits that are lost in the First and Second Class markets.

Similarly, when the access charge for Second Class letters, a_2, is reduced, the supply of Second Class letters by the fringe increases and the PO's production of Second Class letters decreases. In addition, the lower price of the fringe's Second Class letters attracts senders who would not otherwise have participated in the market. Therefore, it must be satisfied that $\sigma_{22} < 1$. Due to the higher participation in the market, the PO's fixed costs can be financed by a greater number of senders and the access charge can be reduced.

Next, I completely solve the problem, faced by the regulator, of calculating the retail and wholesale prices that maximize social welfare.

Proposition 3 *Consider a regulated PO that applies two-tier pricing and competes with a fringe of price-taking rivals. Given the pairs of qualities* (x_1, x_2) *and* (y^{PO}, y^E)*, when* $\lambda > 0$ *the PO's optimal Ramsey prices for First and Second Class letters and the optimal access charges satisfy:*[14]

[14] These results are obtained by differentiating the Lagrangian with respect to the PO's retail prices and the access charges. The first order conditions of this problem are tedious and have been omitted, but they can be obtained by request to the author.

$$p_1^{PO}\left(z_1^{PO}\right) = \frac{\left[c + s\left(z_1^{PO}\right)^2\right](1+\lambda) + z_1^{PO}\overline{\theta}\lambda}{1+2\lambda};$$
$$p_2^{PO}\left(z_2^{PO}\right) = \frac{\left[c + s\left(z_2^{PO}\right)^2\right](1+\lambda) + z_2^{PO}\overline{\theta}\lambda}{1+2\lambda}; \tag{13}$$

$$a_1(x_1) = \frac{\left(c_2 + sx_1^2\right)(1+\lambda) + \left(x_1\overline{\theta} - c_1\right)\lambda}{1+2\lambda};$$
$$a_2(x_2) = \frac{\left(c_2 + sx_2^2\right)(1+\lambda) + \left(x_2\overline{\theta} - c_1\right)\lambda}{1+2\lambda}. \tag{14}$$

Note that with the access charges of Eq. 14 it is straightforward to derive the fringe's equilibrium prices, since $p_j^E = a_j + c_2$. Moreover, observe that when $y^{PO} = 0$ and $c_1 = c_2$, the PO and the fringe offer identical services and their prices are the same.

3.2.2 Quality levels

I finally derive the optimal quality levels, which have a direct influence in the retail and wholesale prices. In context of this deterministic model, I assume that the regulator first determines the degree of product differentiation by setting the PO's private component of quality and afterwards sets the common component of quality (see Appendix).[15]

Proposition 4 *Consider a regulated PO that applies two-tier pricing and competes with a fringe of price-taking rivals. The PO's welfare-maximizing common and private components of quality satisfy:*

$$x_1\left(y^{PO}\right) = \frac{11\overline{\theta} - 14sy^{PO} + \left[60sc + \left(\overline{\theta} - 4sy^{PO}\right)^2\right]^{\frac{1}{2}}}{30s};$$
$$x_2\left(y^{PO}\right) = \frac{\overline{\theta} - 4sy^{PO} + \left[60sc + \left(\overline{\theta} - 4sy^{PO}\right)^2\right]^{\frac{1}{2}}}{10s}; \tag{15}$$

$$y^{PO} = \frac{8\overline{\theta} + \sqrt{\overline{\theta}^2 + 252sc}}{63s}. \tag{16}$$

The PO's private component of quality, y^{PO}, reduces the common components of quality, x_1 and x_2. Furthermore, Eq. 16 shows that the PO's private component of quality increases with collection and delivery cost, but decreases with sorting costs. Indeed,

[15] Alternatively, consider that the PO's private quality is determined exogenously.

when sorting costs increase, the regulator is less interested in increasing product differentiation.

Once the PO's common and private components of quality are known, it is possible to derive the total qualities of First and Second Class letters offered by the PO. Observe that with entry the PO's optimal qualities are always higher than those provided by a monopoly (regulated or unregulated). For example, when $c = 0$ the qualities are $z_1^{PO} = x_1 + y^{PO} = 4\overline{\theta}/9s$ and $z_2^{PO} = x_2 + y^{PO} = 2\overline{\theta}/9s$, which are clearly greater than the qualities generated by a monopoly, $x_1 + y^{PO} = 2\overline{\theta}/5s$ and $x_2 + y^{PO} = \overline{\theta}/5s$.[16]

To sum up, with product differentiation the optimal regulation consists of setting the PO's total quality of First and Second Class mail above the level that would offer a monopoly and the quality of the access services below the level that would offer a monopoly in the retail market. Entry increases the variety of services offered and makes efforts to adapt the categories of letters to the consumers' preferences optimal.

4 Conclusions

The use of a two-tier system in the postal sector reduces the need for processing capacity to satisfy the peak requirements of sorting. In addition, operators are able to offer a range of services more sensitive to consumer preferences. However, in a liberalized market the maintenance of two-tier pricing may be threatened by regulations that facilitate the use of the PO's network by entrants.

This paper has analyzed the regulation of access charges in a liberalized postal sector where operators use two-tier pricing. In contrast to the previous literature, the paper has assumed that the quality of First and Second Class mail is determined by the regulator. In this context, it has been shown that the optimal access charges depend on the quality of mail and on the level of product differentiation.

With product differentiation, entry distorts the industry demand for First and Second Class letters and alters the mechanism used by the PO to finance its fixed costs. In order to control these effects, the regulator can redefine the quality of the retail and access services. By regulating the quality of access it is possible to increase the variety of services offered and the participation in the market.

The results of this paper may provide some insights for regulatory policy in the postal sector. First, those determining access charges should consider both the level of the PO's network at which entrants deliver their letters and the financial burden created by each type of entry. Second, the access charges should reflect the quality of the access services offered. Entry can increase the variety of services provided to senders, but the analysis of this paper shows that this may require regulation of the quality of access.

[16] Numerical examination shows that this result is robust to any value of c. Moreover, it can be shown that when the fringe offers services with a higher quantity than the PO, the regulator finds it optimal to reduce the quality of the services offered by the PO.

Appendix

Proof of Proposition 1 Differentiating the PO's profit in (5) with respect to the prices yields the monopoly prices of the Proposition. To obtain the Ramsey prices differentiate the welfare function in (6) with respect to the prices to obtain the following system of equations, which is solved with the prices of the proposition.

$$\frac{(p_2 - p_1)(1 + 2\lambda) + (x_1 - x_2)\left(\overline{\theta}\lambda + s(1 + \lambda)\right)(x_1 + x_2)}{x_1 - x_2} = 0; \tag{17}$$

$$\frac{(p_1 x_2 - p_2 x_1)(1 + 2\lambda) + s(1 + \lambda)(x_1 - x_2)(1 - x_1 + x_2)}{(x_1 - x_2)x_2} = 0. \tag{18}$$

Substituting the monopoly prices in the profit function and differentiating with respect to the qualities x_1 and x_2 I obtain the qualities in (8). Similarly, substituting the Ramsey prices in (7) and differentiating with respect to the qualities offers the following equations that can be solved simultaneously to obtain the qualities in (8).

$$\frac{(1 + \lambda)^2\left(\overline{\theta}^2 - 4\overline{\theta}s x_1 + s^2\left(3x_1^2 + 2x_1 x_2 - x_2^2\right)\right)}{2 + 4\lambda} = 0; \tag{19}$$

$$\frac{(1 + \lambda)^2\left(c^2 - 2sdx_2^2 - s^2 x_1(x_1 - 2x_2)x_2^2 + 2(c - d)\left(d - sx_2^2\right)\right)}{2(1 + 2\lambda)x_2^2} = 0. \tag{20}$$

Proof of Proposition 4 The optimal qualities are obtained by replacing the prices of Proposition 3 in the welfare function in (11) and differentiation with respect to x_1 and x_2. Finally, substituting x_1^o and x_2^o in the welfare function and maximizing with respect to y^{PO} yields the optimal private component of quality.

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