Efficient Access Pricing and Endogenous Market Structure

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Abstract

We analyze a model of regulated competition in differentiated retail goods and services between an incumbent firm, who owns a network good (an essential input) and a potential entrant, whose cost of production is private information. The regulator sets the retail prices and the access charge that the entrant pays to the incumbent. The decision of the (potential) competitor to enter the retail market crucially depends on the regulatory mechanism, and consequently the market structure is endogenous. We analyze the efficient mechanism that gives rise to a set of "modified" Ramsey prices. We derive a cut-off level of entrant's marginal cost below which the induced market is a duopoly. We show that, under a linear demand system, there is inefficient entry compared to the social optimum.

Keywords: Ramsey pricing, endogenous entry, access pricing.

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1 Introduction

There are industries where the supply of network, which is a key input in the production of final goods and services, is often monopolized by a vertically integrated firm, the owner of such inputs. The challenge then faced by the regulating authority is to design proper access conditions for other firms in order to promote competition in different market segments. In many countries there is a sole owner of the local telecom network, and the long distance carriers pay a stipulated access charge for the use of the local loop to be able to compete in the long distance call market. This is typically known as "one-way access". Other examples of such network are transmission grid (in the generation of electricity), pipelines (in the supply of natural gas), tracks and stations (in railroad transportation) and local delivery network (in postal services). If the monopoly owner of the network also competes in the complementary segments of the market (e.g. retail services), then this firm may use its dominant position to foreclose the market. Hence, the regulator's task lies in designing access charges that are social welfare enhancing.

The economics of efficient access pricing (Laffont and Tirole [11], and Armstrong, Doyle and Vickers [2]) aim at deriving pricing schemes that maximize the social welfare taking into consideration that the firms break even. The efficient access pricing approach prescribes that, for each retail product, the associated Lerner index is inversely related to the demand elasticity (if the firm is a monopolist) or to the superelasticity of the product (if the firms compete in a differentiated duopoly). This approach is popularly known as Ramsey pricing.

In this paper we consider a model of regulated competition to analyze the one-way access problem. There is an incumbent firm, the owner of a network input, who faces a potential competitor in the retail market for a differentiated product (e.g. long distance calls). The cost of production of the potential entrant is unknown to the regulator, who designs the retail prices and the access charge. In our model the regulator, in order to maximize social welfare, sets a uniform mechanism (retail prices and access charge that do not depend on the costs of the entrant). Consequently, the competitor's entry decision crucially depends on the regulatory mechanism. A low access charge or a high retail price implies that the competitor is more likely to realize positive profits, and hence is more likely to enter the retail market. As a result, the market structure is endogenous. In other words, depending on the regulated prices and access charge, the downstream segment of the market is either served only by the incumbent (a monopoly situation) or both the incumbent and the entrant operate (a duopoly situation). It is in this sense that our approach is a departure from the traditional approach to Ramsey pricing (Laffont and Tirole [11]). In the traditional approach the regulator, while designing the optimal mechanism, assumes that duopoly prevails in the retail market.[1] Thus our approach differs in what we endogenize the entry decision, and as a consequence the market structure is also endogenous.

We derive the Ramsey prices both under symmetric and asymmetric information. When the entrant's cost is publicly observed, there is a cut-off level of the entrant's marginal cost above which entry is socially inefficient, and hence the retail market is a monopoly. The Lerner index of the incumbent is inversely proportional to its demand elasticity. When the marginal cost falls below the cut-off level, the regulator allows entry (duopoly regime), and then the Lerner index of each retail product is inversely proportional to its superelasticity. The cut-off marginal cost is referred to as the "socially efficient entry point".

Under asymmetric information (that is, when the entrant's cost is not publicly observable), the retail prices are such that the associated Lerner index for each retail product is inversely related to a "modified superelasticity", which is a weighted arithmetic mean of the demand elasticity in the monopoly regime and the traditional superelasticity (obtained in the symmetric information case) in a differentiated duopoly. The weights given to each of these two terms

[1] Laffont and Tirole [11], and Bloch and Gautier [5] consider the impact that the access price may have on the decision to bypass the existing network.

depend on the probability of entry. More weight is given to the duopoly superelasticity as the probability of entry increases. If entry always occurs, then the market structure is a duopoly and the Lerner index of each firm is inversely proportional to its superelasticity, which is the case with the traditional Ramsey pricing approach. Furthermore, if the incumbent's retail price in a regulated monopoly situation is higher than that in a regulated duopoly situation, then its retail price monotonically decreases with the probability of entry. The consequence of entry on the entrant's retail price is ambiguous. The retail price of the entrant is lower when the market is more competitive, i.e., when the probability of entry increases. On the other hand, an increase in entry also implies that less efficient types enter the market, and this has a positive impact on its retail price. Depending on the relative importance of these two countervailing effects, the entrant's retail price may increase or decrease with the probability of entry.

We also address the issue of optimal entry under asymmetric information and compare it with socially efficient entry. For this analysis we consider a linear demand system for differentiated products popularized by Singh and Vives [15]. We first show that there is a cut-off level of marginal cost above which entry is not profitable, and hence the retail market is served only by the incumbent firm. If the competitor has marginal cost below this cut-off level, then the retail market is a duopoly. We further show that this cut-off level generically falls below the socially efficient entry point. In other words, under linear demand and asymmetric information there is always "too little entry". By too little entry we mean that there exists some types for which entry is not profitable though entry, for these types, is socially efficient.

To derive the optimal pricing schemes, we make the following assumptions. First, we assume that the regulator has the power to set the retail and access prices. This implies that the incumbent is totally passive: it takes prices as given and supplies the quantities that exhaust the demand for its product at these prices. The entrant is also passive with respect to its supply decision but it is active with respect to its entry decision. Second, we assume that the regulator cannot extract the entrant's private information on its cost by using a menu of contracts and has to offer a uniform pricing scheme. This is indeed a source of inefficiency but can be justified by the non-discriminatory rules that a regulator often uses in designing access prices.[2] The analysis of the exact implications of the non-discriminatory access requirement is beyond the scope of the current paper. Interested readers may refer to the discussion in Laffont and Tirole [12], and Pittman [14]. Offering different self-selecting pricing schemes is not *per se* a discriminatory practice since all firms have access to the same pricing schemes. However, the German competitive authority (the Bundeskartellampt) urged the owner of the rail infrastructure, DB Netz, to remove its TPS98 tariff for access because it was considered as discriminatory. The TPS98 consisted of two different pricing schemes: a two-part tariff for larger carriers and a per-unit access charge for smaller carriers (see Pittman [14]).

The current model resembles two strands of the existing literature: the efficient access pricing literature and the literature on regulation with endogenous market structure. There are two approaches to this latter problem. The first one, following Dana and Spier [7], Auriol and Laffont [3], and Jehiel and Moldovanu [10], considers that the regulator designs the market structure and selects the firms which are awarded the right to operate on the retail market as a function of their reported costs. The other approach assumes that the regulator does not regulate the market structure ex-ante, but specifies the regulatory environment ignoring the cost of the competitor(s). When these costs realize, the competitors take the decision on whether or not to operate in the retail market. Caillaud [6] considers a competitive fringe that has the alternative technology to bypass a regulated firm, and may decide to do so depending on the regulated price. Gautier and Mitra [9] consider an environment where the firms produce homogenous products and compete sequentially in quantities. In their model, the market structure is endogenous, and

[2] In the ongoing liberalization process in Europe, the European directives on telecommunication (90/388/EEC), electricity (96/92/EC), gas (2003/55/EC), rail (2002/14/EC) and postal services (96/67/EC) impose that the owners of essential facilities must grant access to competitors on the basis of a "transparent and non-discriminatory" tariff.

they show the possibility of inefficient entry.

As an alternative to Ramsey pricing, the efficient component pricing rule (ECPR) (see Armstrong [1], and Baumol, Panzar and Willig [4]) prescribes that the access price should be equal to the incumbent's opportunity cost of providing access. Under ECPR, (a) potential entrants can enter the market only if they are more cost efficient and (b) entry is neutral with respect to the incumbent's profit. In this approach, entry is endogenous and the market is always served by the most efficient firm. Under some conditions (price competition, homogenous products) the ECPR is equivalent to Ramsey pricing (see Armstrong, Doyle and Vickers [2], and Laffont and Tirole [12]). Our approach also takes into account, as does the ECPR, the entry decision of the competitor while designing the retail and access prices. But, we consider an environment where the regulator's objective is not the selection of the most efficient firm but welfare maximization. Clearly, these two objectives do not coincide when products are differentiated.

2 The Model

We consider an economy with two firms. Firm 1, the incumbent, is a vertically integrated firm which owns a network good (e.g. local loop) that cannot be cheaply duplicated, and it produces a retail good (long distance calls). Firm 2 is a potential competitor in the retail market that produces and sells an imperfect substitute of the retail good produced by firm 1. Production of one unit of a retail good uses a unit of the network good. If the retail market is served by at least one firm, the incumbent has to produce positive amount of the network for which it incurs a fixed cost k_0 and per unit cost $c_0 > 0$. The production of the retail good i involves a constant positive marginal cost c_i for $i = 1, 2$. Suppose firm i produces an amount $x_i \geq 0$ of its retail good. Then the total cost for firm 1 to provide network is $k_0 + c_0(x_1 + x_2)$. If firm 2 operates in the retail market then it has to pay a per unit access charge α.

The cost parameters k_0, c_0 and c_1 of the incumbent firm is publicly observable. Entrant's marginal cost c_2 is distributed according to a probability distribution function $G(c_2)$ in the support $[\underline{c}_2, \bar{c}_2] \subset \mathbf{R}_{++}$. Let $g(c_2)$ be the continuous and differentiable density associated with $G(c_2)$. The probability distribution of c_2 is common knowledge, and we assume that $g(c_2) > 0$ for all $c_2 \in [\underline{c}_2, \bar{c}_2]$.

We consider a fully regulated market where a utilitarian regulator sets the retail prices p_1 and p_2 and the access charge α in order to maximize social welfare. We adopt the accounting convention that the regulator collects the total sales revenue of firm 1, $p_1 x_1$, and reimburses the incumbent its costs of network with monetary transfers, and that the entrant pays the total access receipt, αx_2, directly to firm 1. Since the net utility of the incumbent firm must be non-negative, the welfare maximization problem induces prices that are similar to Ramsey prices. In this environment, the only decision firm 2 takes is whether or not to sell a positive quantity of its retail good depending on the regulatory mechanism.

Regulating retail prices in addition to the access conditions is of particular importance when the entrant firm possesses market power in the downstream segment. The regulator needs at least two instruments, namely, the retail price (to regulate its supply) and the access charge (to regulate its contribution to the network financing), with both instruments having an impact on the entry decision.[3] Had the entrant belonged to a competitive fringe, only one regulatory instrument (say, the access charge) would have been sufficient.

Consumers have quasilinear preferences. The gross consumer surplus from the downstream products is given by $U(x_1, x_2)$, where U is the indirect utility function. Demand functions are

[3] Alternatively, the regulator can use a two-part tariff, where the variable part aims at regulating its supply and the fixed part is used for regulating its contribution to the network financing. Gautier and Mitra [9], and Lewis and Sappington [13] use two-part tariff to regulate the behavior of a non-competitive entrant.

derived from

$$\max_{x_1, x_2 \geq 0} U(x_1, x_2) - p_1 x_1 - p_2 x_2.$$

When any one of the two firms is inactive (i.e., product j is not supplied), the monopoly demand for product i is found by solving the above problem with $x_j = 0$.[4]

The demand for the retail goods at prices (p_1, p_2) faced by firm 1 is given by:

$$x_1 = \begin{cases} x_1^d(p_1, p_2), & \text{if firm 2 enters,} \\ x_1^m(p_1, .), & \text{if firm 2 does not enter.} \end{cases}$$

The demand faced by firm 2 is $x_2 = x_2^d(p_1, p_2)$. Let η_i and η_{ij}, for $i, j = 1, 2$, be the own and cross price elasticities of x_i^d, respectively, and let ε_1 be the own price elasticity of x_1^m. Products are substitutes if $\eta_{ij} > 0$ for $i, j = 1, 2$, and $i \neq j$ and complements if $\eta_{ij} < 0$.

The timing of the events is as follows. Firm 2 learns its marginal cost c_2 privately. Then the regulator sets the regulatory mechanism (p_1, p_2, α). After being offered the mechanism (p_1, p_2, α), firm 2 makes the entry decision. If it decided to enter the retail market, the firms sell quantities $x_i^d(p_1, p_2)$ for $i = 1, 2$. Otherwise, firm 1 sells quantity $x_1^m(p_1, .)$ as a monopolist in the downstream market. In the following sections, we analyze the optimal regulatory mechanism both under symmetric (when the marginal cost of firm 2 is known to the regulator) and asymmetric information.

[4] The monopoly demand function is equal to the duopoly demand function for good i when firm j charges a limit price such that, at this limit price, the demand for good j is equal to zero.

3 Optimal Regulation under Symmetric Information

3.1 Duopoly Market Structure

In this section we assume that c_2 is publicly observable. First we consider the case of a duopoly market. The utilitarian regulator maximizes social welfare by setting the retail prices (p_1, p_2) and the access charge α. The welfare is defined as the sum of consumers and producers surplus. We assume, without loss of generality, that the regulator reimburses costs of the incumbent firm through a monetary transfer t, receives the sales revenue of the incumbent from the retail market, and that the entrant pays the total access fee directly to the incumbent firm. In order to reimburse firm 1 for providing access to the entrant firm, the regulator must raise the amount $t + k_0 + c_0\left(x_1^d + x_2^d\right) - (p_1 - c_1)x_1^d$, which has a shadow price $1 + \lambda$ (with $\lambda > 0$). Hence, the net consumer surplus is given by

$$V^d \equiv U\left(x_1^d, x_2^d\right) - p_1 x_1^d - p_2 x_2^d - (1+\lambda)\left[t + k_0 + c_0\left(x_1^d + x_2^d\right) - (p_1 - c_1)x_1^d\right]. \tag{1}$$

The gross surplus from consuming the downstream products, $U\left(x_1^d, x_2^d\right)$, is assumed to be concave. Given the regulatory mechanism, both the firms must break even. The regulator makes a transfer of amount t to the incumbent firm and this firm is paid a total access receipt αx_2 by the entrant. The sum of these two terms, which is its profit, must be non-negative.

$$\Pi_1^d \equiv t + \alpha x_2^d \geq 0. \tag{2}$$

On the other hand, the net profit of the entrant must also be non-negative, i.e.,

$$\Pi_2^d \equiv (p_2 - c_2 - \alpha)x_2^d \geq 0. \tag{3}$$

The above restrictions are the participation constraints of firms 1 and 2, respectively. The optimal regulatory mechanism results from, subject to (2) and (3), the maximization of

$$V^d(p_1, p_2) + \Pi_1^d(p_1, p_2) + \Pi_2^d(p_1, p_2).$$

Since public funds are costly ($\lambda > 0$), the participation constraint of firm 1 binds at the optimum. Also, the access price α is set to ensure that firm 2 breaks even. Taking these facts into account, the regulator's objective reduces to:

$$\max_{p_1, p_2} W^d \equiv U\left(x_1^d, x_2^d\right) - (1+\lambda)\left[k_0 + (c_0+c_1)x_1^d + (c_0+c_2)x_2^d\right] + \lambda\left(p_1x_1^d + p_2x_2^d\right). \quad (4)$$

In the following proposition we describe the optimal mechanism as a solution to the regulator's maximization problem.

***Proposition* 1** *The optimal regulatory mechanism* (p_1^d, p_2^d, α^d) *under symmetric information is a solution to the following conditions:*

$$L_i^d \equiv \frac{p_i^d - c_0 - c_i}{p_i^d} = \frac{\lambda}{1+\lambda}\frac{1}{\hat{\eta}_i}, \text{ for } i = 1, 2, \quad (5)$$

$$\alpha^d = p_2^d - c_2 = c_0 + \frac{\lambda}{1+\lambda}\frac{p_2^d}{\hat{\eta}_2}, \quad (6)$$

where $\hat{\eta}_i$ *is the superelasticity of good i, which is given by*

$$\hat{\eta}_i \equiv \frac{\eta_i(\eta_i\eta_j - \eta_{ij}\eta_{ji})}{\eta_i\eta_j + \eta_i\eta_{ij}}, \text{ for } i, j = 1, 2.$$

Proof. See Appendix A. ||

The superelasticity of good $i = 1,2$ takes into account the fact that the two firms sell differentiated products in the retail market. If the goods are substitutes (complements) we have $\hat{\eta}_i < (>) \eta_i$. Further, the Lerner index L_i^d of firm i is inversely related to its superelasticity. In the above proposition the formula for the optimal access price has a very simple interpretation. Had the public fund not been costly (i.e., if $\lambda = 0$), the regulator would optimally set the access charge equal to the marginal cost of firm 1 for providing access to the entrant (i.e., $\alpha^d = c_0$). Since public funds are costly due to distortionary taxes, the optimal access charge is the sum of the marginal cost of providing access and a markup involving the superelasticity of the retail good supplied by firm 2 in the downstream market. The magnitude of this markup depends positively on the shadow cost of public funds.

3.2 Monopoly Market Structure

Consider the case of a monopoly downstream market, i.e., the incumbent faces no rival in this segment of the market. In this case the total funds to be raised are given by:

$$t + k_0 + c_0 x_1^m - \left(p_1 x_1^m - c_1 x_1^m\right).$$

Hence, the net consumer surplus is given by:

$$V^m \equiv U\left(x_1^m, 0\right) - p_1 x_1^m - (1+\lambda)\left(t + k_0 + c_0 x_1^m + c_1 x_1^m - p_1 x_1^m\right). \tag{7}$$

In this case also firm 1 must break even. Notice that, since firm 2 does not enter the market, the incumbent does not have to provide access, and hence does not get any access receipt. Its cost is only reimbursed through the net transfer $t \geq 0$ from the regulator. This is the participation constraint of the incumbent firm, which binds at the optimum. Incorporating the participation constraint, the utilitarian regulator selects the retail price p_1 to maximize the following social welfare

$$W^m \equiv U(x_1^m, 0) + \lambda p_1 x_1^m - (1+\lambda)[(c_0+c_1)x_1^m + k_0], \tag{8}$$

The optimal retail price p_1^m is summarized in the following proposition.

***Proposition* 2** *The optimal retail price p_1^m under symmetric information is a solution to the following condition:*

$$L_1^m \equiv \frac{p_1^m - c_0 - c_1}{p_1^m} = \frac{\lambda}{1+\lambda}\frac{1}{\varepsilon_1}. \tag{9}$$

Proof. See Appendix A. ||

In this case the Lerner index of firm 1 is inversely related to the own price elasticity of its retail product. It is immediate to show that if $\hat{\eta}_1 > \varepsilon_1$, the regulated price of good 1 is higher in the case of monopoly than that in duopoly. If the demands are not "too" concave, then at a given price p_1, $\eta_1 \geq (\leq)\varepsilon_1$ if the products are substitutes (complements). But we cannot infer from the substitute or complement nature of the goods whether $\hat{\eta}_1$ is greater or smaller than ε_1. In our linear demand example in Section 5 we have $\eta_1 > \hat{\eta}_1 = \varepsilon_1$ for substitutes products, and $\eta_1 < \hat{\eta}_1 = \varepsilon_1$ for complements.

3.3 Socially Optimum Entry Point

Now we would like to see if, under symmetric information, entry is socially efficient. In other words, we would look for a cut-off level of marginal cost of firm 2 such that if c_2 is different from this cut-off level, maximum social welfare associated to duopoly differs from that in the case of monopoly. This result is summarized in the following proposition.

***Proposition* 3** *There exists a cut-off level of entrant's marginal cost, c_2^* such that if the entrant's* *marginal cost falls below this level then the maximized value of social welfare in duopoly retail market is higher than that in the monopoly situation, and hence entry is socially efficient. If the entrant has marginal cost above this cut-off level, then entry is not socially efficient, and the retail market is served only by firm 1.*

Proof. See Appendix A. ||

The cut-off level of the marginal cost of firm 2, c_2^*, which is referred to as the "socially optimal entry point", is found by equating the maximized values of welfare in the duopoly and the monopoly regimes. For low values of firm 2's marginal cost (i.e., $c_2 \leq c_2^*$) allowing firm 2 to operate in the downstream segment of the market is socially efficient (since, in this case, the social welfare is higher). If the entrant's marginal cost is very high (i.e., $c_2 > c_2^*$), then prohibiting firm 2 to enter the downstream market and allowing firm 1 to be the sole supplier of the retail good is socially optimal.

4 Optimal Regulation under Asymmetric Information

In this section we assume that firm 2 learns its marginal cost privately before the regulator designs the mechanism (p_1, p_2, α) and that the distribution, $G(c_2)$, is common knowledge. The regulatory mechanism is non-discriminatory in the sense that it does not depend on the marginal cost of firm 2. After observing the regulatory mechanism, firm 2 takes its entry decision. Hence, the regulator, while designing the mechanism, knows that firm 2 may enter the market with some probability. As opposed to the case of symmetric information, the regulator maximizes the expected value of the social welfare, since the retail market is served by both the firms with some probability, and only by the incumbent with the complementary probability. The optimal regulatory mechanism has significant impact on the entry decision of firm 2.

4.1 The Regulatory Problem

After being offered the regulatory mechanism firm 2 decides to enter the retail market if it earns non-negative profits, i.e., if $\Pi_2^d \equiv (p_2 - c_2 - \alpha)x_2^d(p_1, p_2) \geq 0$. We assume that at the regulated prices (p_1, p_2), firm 2 faces strictly positive demand for its product, i.e., $x_2^d(p_1, p_2) > 0$. Now define a cut-off marginal cost of firm 2, $\hat{c}_2$ such that $\Pi_2^d(\hat{c}_2) = 0$. At prices (p_1, p_2, α), we have $\partial\Pi_2^d/\partial c_2 < 0$. Therefore firm 2 is active in the downstream market only if $c_2 \leq \hat{c}_2$. Given the assumption of positive demand for the retail product of firm 2, the cut-off entry point $\hat{c}_2$ is defined by

$$p_2 - \hat{c}_2 - \alpha = 0. \tag{10}$$

Thus, given the regulatory mechanism, it is clear that the cut-off marginal cost of firm 2, and hence the market structure (duopoly or monopoly) are endogenous. From the above discussion we can immediately conclude that with probability $G(\hat{c}_2)$ the market structure is a duopoly, and the incumbent is a monopolist in the retail market with the complementary probability.

Irrespective of whether firm 2 enters the market or not, firm 1 receives the monetary transfer t from the regulator to reimburse its cost. If firm 2 enters the retail market (with probability $G(\hat{c}_2)$), then only the incumbent receives the access charge. The participation constraint of firm 1 then implies that the expected profit is non-negative, i.e.,

$$E\,\Pi_1 \equiv t + G(\hat{c}_2)\alpha x_2^d(p_1, p_2) \geq 0. \tag{11}$$

The optimal regulatory mechanism (p_1, p_2, α) results from, subject to (10) and (11), the maximization of

$$
\begin{aligned}
&\left[\int_{\underline{c}_2}^{\hat{c}_2}\left[\left\{U\left(x_1^d(p_1, p_2), x_2^d(p_1, p_2)\right) - p_1 x_1^d(p_1, p_2) - p_2 x_2^d(p_1, p_2)\right\}\right.\right.\\
&-\left\{(1+\lambda)\left(t + c_0\left(x_1^d(p_1, p_2) + x_2^d(p_1, p_2)\right) + k_0 - (p_1 - c_1)x_1^d(p_1, p_2)\right)\right\}\\
&\left.\left.+\{t + \alpha x_2^d(p_1, p_2)\} + \{(p_2 - c_2 - \alpha)x_2^d(p_1, p_2)\}\right] dG(c_2)\right]\\
+&\left[\int_{\hat{c}_2}^{\bar{c}_2}\left[\{U\left(x_1^m(p_1, .), .\right) - p_1 x_1^m(p_1, .)\}\right.\right.\\
&\left.\left.-\{(1+\lambda)\left(t + c_0 x_1^m(p_1, .) + k_0 - (p_1 - c_1)x_1^m(p_1, .)\right)\} + t\right] dG(c_2)\right]
\end{aligned}
\tag{12}
$$

It is easy to check that the above optimization problem is strictly concave. Given (10), the regulator choosing a mechanism (p_1, p_2, α) is equivalent to choosing $(p_1, p_2, \hat{c}_2)$. Since public funds are costly, the participation constraint of firm 1 binds at the optimum. Hence, the regulator's objective reduces to:

$$
\max_{p_1, p_2, \hat{c}_2} G(\hat{c}_2)\widehat{W}^d(\hat{c}_2) + [1 - G(\hat{c}_2)]W^m + x_2^d(p_1, p_2)\int_{\underline{c}_2}^{\hat{c}_2} G(c_2)\,dc_2, \tag{13}
$$

where W^m is defined in (8), and $\widehat{W}^d(\hat{c}_2)$ is given by

$$
\begin{aligned}
\widehat{W}^d(\hat{c}_2) \equiv\, & U\left(x_1^d(p_1, p_2), x_2^d(p_1, p_2)\right) - (1+\lambda)\left[(c_0 + c_1)x_1^d(p_1, p_2) + (c_0 + \hat{c}_2)x_2^d(p_1, p_2) + k_0\right]\\
& + \lambda\left[p_1 x_1^d(p_1, p_2) + p_2 x_2^d(p_1, p_2)\right].
\end{aligned}
$$

The first term in (13) is the expected social welfare with duopoly evaluated at the entrant's marginal cost $\hat{c}_2$, the second term is the expected social welfare under monopoly and the last term measures the expected benefit of having an entrant producing the quantity $x_2^d(p_1, p_2)$ at marginal cost c_2 rather than at $\hat{c}_2$, i.e., the expected profit of firm 2 for having entered with a more efficient type than $\hat{c}_2$.

4.2 The Modified Superelasticity

In the optimal regulatory mechanism under asymmetric information, the Lerner index of each retail product is inversely related to a "modified superelasticity" which is composed of the own price elasticity and the standard superelasticity (the one that has been derived under symmetric information). Prior to analyzing the optimal regulatory mechanism, we discuss the properties of these modified superelasticities. Let the average demands of the retail goods 1 and 2, respectively be

$$\bar{x}_1(p_1, p_2) = G(\hat{c}_2)x_1^d(p_1, p_2) + [1 - G(\hat{c}_2)]x_1^m(p_1, .) \tag{14}$$

$$\bar{x}_2(p_1, p_2) = G(\hat{c}_2)x_2^d(p_1, p_2). \tag{15}$$

Further, let $\bar{\eta}_i$ and $\bar{\eta}_{ij}$ be the own and cross price elasticities associated with these average demands, which are given by

$$\bar{\eta}_i = -\frac{\partial \bar{x}_i(p_1, p_2)}{\partial p_i}\frac{p_i}{\bar{x}_i}, \tag{16}$$

$$\bar{\eta}_{ij} = \frac{\partial \bar{x}_i(p_1, p_2)}{\partial p_j}\frac{p_j}{\bar{x}_i}, \tag{17}$$

for $i, j = 1, 2$ and $i \neq j$. We define the modified superelasticities of the retail products as

$$\hat{\eta}_i^G = \frac{\bar{\eta}_i\left(\bar{\eta}_i\bar{\eta}_j - \bar{\eta}_{ij}\bar{\eta}_{ji}\right)}{\bar{\eta}_i\bar{\eta}_j + \bar{\eta}_i\bar{\eta}_{ij}}, \quad \text{for } i, j = 1, 2, \text{ and } i \neq j. \tag{18}$$

The above modified superelasticities are similar to those in case of symmetric information. Under unknown marginal cost of firm 2, the terms η_i, η_{ij} and η_{ji} in $\hat{\eta}_i$ are replaced by $\bar{\eta}_i$, $\bar{\eta}_{ij}$ and $\bar{\eta}_{ji}$ in $\hat{\eta}_i^G$, respectively. In other words, the modified superelasticities are defined in terms of the expected demands. Therefore, they depend on the entry decision of firm 2 (since $G(\hat{c}_2)$

is the fraction of cost types that enter the retail market). It is worth noting a few important properties of the modified superelasticities described in (18). First, the modified superelasticity of retail good i (=$1,2$) can be expressed as a weighted arithmetic mean of its superelasticity obtained under symmetric information and its own price elasticity. Take the retail product of firm i. Its modified superelasticity can be written as the following.[5]

$$\hat{\eta}_1^G = \theta_1(\hat{c}_2)\hat{\eta}_1 + [1-\theta_1(\hat{c}_2)]\varepsilon_1\,, \tag{19}$$

$$\hat{\eta}_2^G = \theta_2(\hat{c}_2)\hat{\eta}_2 + [1-\theta_2(\hat{c}_2)]\delta\eta_2\,, \text{ with } \delta = \frac{\varepsilon_1}{\varepsilon_1+\eta_{21}}. \tag{20}$$

The weights depend on the probability of entry, $G(\hat{c}_2)$. Had all types of firm 2 been allowed to enter the retail market, i.e., if $\hat{c}_2 = \overline{c_2}$, then $\theta_i(\hat{c}_2)$ equals 1 for $i = 1,2$. In this case, the retail market is duopoly with probability 1, and the modified superelasticities coincide with the superelasticities derived under symmetric information, $\hat{\eta}_1$ and $\hat{\eta}_2$, respectively. If no types of firm 2 are allowed entry, i.e., $\hat{c}_2 = \underline{c}_2$, then the retail market is served only by the incumbent, and hence, $\hat{\eta}_1^G$ equals ε_1, the own price elasticity associated with the monopoly demand faced by firm 1. In this case, firm 2 does not produce, and its own price elasticity is not well defined. From (20) it is easy to show that as $G(.)$ approaches zero, $\hat{\eta}_2^G$ tends to η_2.

Next, important property is related to the behavior of modified superelasticities vis-à-vis the probability of entry. From (19) and (20) it is immediate to show that, for $i = 1,\,2$,

$$\frac{\partial\,\hat{\eta}_i^G}{\partial\,G(.)} \gtrless 0 \;\text{ as }\; \hat{\eta}_1 \gtrless \varepsilon_1\,.$$

Hence, the modified superelasticities can either increase or decrease montonically as the probability of entry increases. In fact, both $\hat{\eta}_1^G$ and $\hat{\eta}_2^G$ move in the same direction with respect to

[5]See Appendix B for details.

the probability of entry.[6]

Finally, notice that if the retail goods are (imperfect) substitutes, then $\bar{\eta}_{ij} > 0$ for $i, j = 1, 2$ and $i \neq j$. Then one can immediately show that in this case $\hat{\eta}_i^G < \bar{\eta}_i$ for $i = 1, 2$. The inequality is reversed if the products are complements.

4.3 Efficient Prices and Access Charge

In this subsection we analyse the optimal regulatory mechanism as a solution to the welfare maximization problem (13) of the regulator. The optimal retail prices and the access charge are modified Ramsey prices which takes the endogeneity of the market structure into account. These are described in the following proposition. The mechanism is efficient in the sense that it maximises the expected social welfare.

***Proposition* 4** *Under asymmetric information, the welfare maximizing prices* (p_1, p_2, α) *are solutions to the following conditions:*

$$L_1^G \equiv \frac{p_1 - c_0 - c_1}{p_1} = \frac{\lambda}{1+\lambda}\frac{1}{\hat{\eta}_1^G}, \tag{21}$$

$$L_2^G(c_2) \equiv \frac{p_2 - c_0 - c_2}{p_2} = \frac{\lambda}{1+\lambda}\frac{1}{\hat{\eta}_2^G} + \frac{(1+\lambda)(\hat{c}_2 - c_2) - (\hat{c}_2 - \mu_2(\hat{c}_2))}{p_2(1+\lambda)}, \tag{22}$$

$$\alpha = p_2 - \hat{c}_2 = c_0 + \frac{\lambda}{1+\lambda}\frac{p_2}{\hat{\eta}_2^G} - \frac{\hat{c}_2 - \mu_2(\hat{c}_2)}{1+\lambda}, \tag{23}$$

where $\mu_2(\hat{c}_2) = \mathbf{E}[c_2 | c_2 \leq \hat{c}_2] = \hat{c}_2 - \frac{\int_{\underline{c}_2}^{\hat{c}_2} G(c_2) dc_2}{G(\hat{c}_2)}$ *is the expected marginal cost conditional on entry.*

Proof. See Appendix B. ||

[6] The above two properties should be interpreted with caution. They are valid for exogenous values of $\hat{c}_2$. In the subsequent sections we show that the entry decision, and hence, $\hat{c}_2$ are endogenously determined. Thus at the optimum, the behavior of modified superelasticities with respect to the probability of entry is somehow redundant.

When the marginal cost of firm 2 is unknown, the Lerner index of firm 1 is equal to a Ramsey like term, which is inversely proportional to the modified superelasticity of its product. It takes into account that the retail market is a duopoly with probability $G(\hat{c}_2)$. Therefore, the Lerner index of firm 1 can be expressed as a weighted mean of the Lerner index of the incumbent under monopoly and that under duopoly with symmetric information.

***Corollary* 1** *Under asymmetric information, the Lerner index of firm 1 is a weighted harmonic mean of L_1^d and L_1^m, the weights being functions of the probability of entry.*

Proof. See Appendix B. ||

The above corollary immediately follows from (19). This result implies that if $\hat{c}_2 = \underline{c}_2$, $\hat{\eta}_1^G = \varepsilon_1$, and hence we have $L_1^G = L_1^m$. Similarly, if entry always occurs with probability 1 (i.e., $\hat{c}_2 = \overline{c}_2$), then we have $L_1^G = L_1^d$.

The optimal retail price of good 2 is determined from (22). The Lerner index of firm 2 consists of three terms which we explain below.

1. The first term is a Ramsey like term which is inversely proportional to the modified superelasticity of the product.

2. The second term depends positively on the ratio of the difference between $\hat{c}_2$ and the true realization of c_2 to the price of good 2. In the optimal non-discriminatory mechanism, all types c_2 face the same price p_2. Consequently, all the types that find it profitable to enter the downstream market enter and sell the same quantity x_2^d at price p_2. However, the profit level of an entrant is type-contingent and it increases monotonically with its level of cost efficiency (that is, lower the marginal cost higher is the profit). This is captured in the second term.

3. The third term depends negatively on the ratio of the difference between the cost of the

marginal entrant and the expected cost of the potential entrant (given the entry cut-off $\hat{c}_2$) to the mark up price $(1+\lambda)p_2$ where the mark up internalizes the shadow cost λ. This is the common cost of all potential entrants (that is, entrants with type $c_2 \leq \hat{c}_2$).

The second and third term taken together gives us

$$\frac{(1+\lambda)(\hat{c}_2 - c_2) - (\hat{c}_2 - \mu_2)}{p_2(1+\lambda)},$$

and we call this the "impact-of-entry" term. The role of the "impact of entry term" becomes more transparent if one re-writes the Lerner index of firm 2 (that is, condition (22)) as a 'virtual' Lerner index of firm 2 in the following way:

$$L_2^G(z(\hat{c}_2)) \equiv \frac{p_2 - c_0 - z(\hat{c}_2)}{p_2} = \frac{\lambda}{1+\lambda}\frac{1}{\hat{\eta}_2^G}, \tag{24}$$

where $z(\hat{c}_2)$ is the virtual cost of the endogenously determined marginal entrant $\hat{c}_2$ under the optimal non-discriminatory regulatory mechanism,[7] which is given by

$$z(\hat{c}_2) = \hat{c}_2 - \frac{\int_{\underline{c}_2}^{\hat{c}_2} G(c_2)dc_2}{(1+\lambda)G(\hat{c}_2)}.$$

Therefore, the pricing rule under asymmetric information is such that the virtual Lerner index of firm 2 is inversely related to the modified superelasticity.

We now analyze the impact of the endogenous probability of entry on the regulated prices. Under symmetric information, the Lerner index of firm 1 in case of duopoly may be higher or lower than that of monopoly depending on whether $\hat{\eta}_1$ is lower or higher than ε_1, and hence the retail price p_1^d may be higher or lower than the retail price p_1^m. We can conclude that, if $p_1^d \leq (\geq) p_1^m$, then a greater probability of entry is associated with a lower (higher) price for

[7] In the objective function (13), we have $\frac{\partial \hat{W}^d(\hat{c}_2)}{\partial \bar{x}_2} = (1+\lambda)(p_2 - c_0 - z(\hat{c}_2))$.

good 1.

In case of the regulated price of firm 2, a similar monotonicity result cannot be drawn. Higher probability of entry has the same qualitative impact on the Ramsey term in (21) as on that in (22). But a higher probability of entry also has a positive impact on the virtual marginal cost $z(\hat{c}_2)$ and hence on the retail price p_2. Hence, if $p_1^m \geq p_1^d$, the impact of a higher probability of entry on the regulated retail price p_2 is ambiguous.

In line with the traditional approach to efficient access pricing as in Laffont and Tirole [11], when the cost of the entrant is unknown to the regulator, the firms are offered a menu of contracts $(p_1(c_2), p_2(c_2), \alpha(c_2))$. Consequently, entry and hence the market structure are perfectly regulated. There is no entry decision per se made by firm 2. In the current paper we set up a model similar to that in Laffont and Tirole [11] in order to derive welfare maximising retail and access prices that also take efficient entry decision into account, but we add a non-discriminatory clause to the problem. This implies that prices cannot be contingent on a revealed value of the entrant's marginal cost. Our modified Ramsey prices bear close relation to the optimal regulatory mechanism based on the "revelation principle", as analyzed by Laffont and Tirole [11]. Following their set-up, the optimal retail prices $(p_1(c_2), p_2(c_2))$ (under asymmetric information) are given by:

$$L_1 \equiv \frac{p_1(c_2) - c_0 - c_1}{p_1(c_2)} = \frac{\lambda}{1+\lambda} \frac{1}{\hat{\eta}_1}, \tag{25}$$

$$L_2 \equiv \frac{p_2(c_2) - c_0 - c_2}{p_2(c_2)} = \frac{\lambda}{1+\lambda} \frac{1}{\hat{\eta}_2} + \frac{h(c_2)}{p_2(c_2)}, \tag{26}$$

where $h(c_2) = G(c_2)/g(c_2)$, the hazard rate associated with the distribution function $G(c_2)$.[8] In light of (25), firm 1 always receives an efficient (non-distortionary) contract since its characteristics are public information. This is not the case with firm 2. In (26), the Ramsey markup

[8]These contracts apply only if, under asymmetric information, a duopoly market structure is prefered to a monopoly which is the case for all types of firm 2 such that $c_2 + h(c_2) \leq c_2^*$.

term involves the superelasticity of good 2, and the additional term is an "incentive correction" term that depends on the hazard rate. The most efficient type of firm 2 ($c_2 = \underline{c}_2$) receives a non-distortionary contract, i.e., the optimal contract under symmetric information. In our pricing formula (21) superelasticity of good 1 is replaced by its modified superelasticity in the markup term. Hence firm 1 does not receive an efficient contract, since at the time of designing the regulatory contract, firm 2's entry decision is not known. Only when the retail market is served by both the firms with probability 1 (i.e., $\hat{c}_2 = \bar{c}_2$), firm 1 receives an efficient contract, since $\hat{\eta}_1^G = \hat{\eta}_1$.

In our model it is impossible to offer a non-distortionary contract to firm 2, since entry cannot be perfectly regulated. An alternate way of representing firm 2's Lerner index (that is, condition (22)) is the following:

$$L_2^G(c_2) \equiv \frac{p_2 - c_0 - c_2}{p_2} = \frac{\lambda}{1+\lambda}\frac{1}{\hat{\eta}_2^G} + \frac{\left(\frac{\mu_2(\hat{c}_2)+\lambda\hat{c}_2}{1+\lambda}\right) - c_2}{p_2} \tag{27}$$

A comparison between (26) and (27) shows that our Lerner index differs both in the Ramsey type term as well as in the adjustment term. While the Ramsey type term differs mainly because of the endogenous market structure, the adjustment term differs mainly because, as opposed to the traditional approach where entry is exogenously given, in our problem the endogenously determined entry cut-off point $\hat{c}_2$ matters.

4.4 Endogenous Entry

We analyze how the optimal cut-off point for entry $\hat{c}_2$ is related to the socially efficient entry point c_2^*. Under asymmetric information entry is inefficient if $\hat{c}_2$ differs from c_2^*. There are two possible forms of inefficiency: "excess entry" under asymmetric information if $\hat{c}_2 > c_2^*$, and "too little entry" if $\hat{c}_2 < c_2^*$. To be more specific, too little entry refers to the situation if the entry cut-off point under asymmetric information, $\hat{c}_2$ falls below the socially optimal entry point, c_2^*. In other words, there are values of marginal cost of firm 2 ($c_2 \in [\hat{c}_2, c_2^*]$) allowing whom to enter the retail market is socially desirable, but under the optimal regulatory mechanism these types do not enter since they do not find it profitable to do so. In a related work, Gautier and Mitra [9] show that if the incumbent and entrant produce a non-differentiated good then, under asymmetric information, entry is generically inefficient and that both types of inefficiencies are possible. Thus, there is no systematic bias towards any particular form of inefficiency. In more specific contexts, i.e., using specific assumptions on the distribution of the entrant's cost parameter, Bloch and Gautier [5], and Gautier [8] identify situations where a particular type of inefficient entry emerges. Gautier [8] observes that there is too little entry with both two-part and single tariffs for the access charge, the latter generating more entry. Bloch and Gautier [5] study the choice between access and bypass as a function of the regulated access price. They identify a situation where, under asymmetric information, excessive bypass is possible, while excess access does not emerge.

In our set-up, the optimal cut-off of the marginal cost of firm 2 is given by

$$\widehat{W}^d(\hat{c}_2) - W^m = \lambda h(\hat{c}_2) x_2^d(p_1, p_2). \tag{28}$$

From the above first order condition, we can only conclude that there is entry if and only if the duopoly welfare evaluated at the marginal entrant's marginal cost is higher than the monopoly welfare. Otherwise, there is no entry. To draw an explicit conclusion regarding the types of inefficiencies, we analyze a differentiated good retail market with linear demands.

5 Optimal Regulation with Linear Demands

We assume that the consumers have quasilinear preferences over the retail products (x_1, x_2) and a numeraire good z. Thus, consumers maximize $U(x_1, x_2) + z$ subject to $p_1x_1 + p_2x_2 + z \leq I$, where I represents consumers' total wealth. As in Singh and Vives [15], we assume that the gross surplus over the products of the two firms is a quadratic function.

$$U(x_1, x_2) = a_1x_1 + a_2x_2 - \frac{1}{2}\left(b_1x_1^2 + b_2x_2^2\right) - \beta x_1x_2 \,. \tag{29}$$

We assume that a_i, b_i, $b_i b_j - \beta^2$, and $a_i b_j - a_j \beta$ are all positive for i, $j = 1, 2$.

When the retail market is served by both the firms, the first order condition of the consumer's optimization problem gives rise to the inverse demand functions.

$$\begin{aligned} p_1(x_1, x_2) &= a_1 - b_1x_1 - \beta x_2, \\ p_2(x_1, x_2) &= a_2 - b_2x_2 - \beta x_1. \end{aligned}$$

For a monopoly retail market, we have $x_2 = 0$ and hence, the gross consumers' surplus is given by.

$$U(x_1, 0) = a_1x_1 - \frac{b_1}{2}x_1^2.$$

Hence, the inverse demand function is given by:

$$p_1 = a_1 - b_1x_1.$$

For substitute products ($\beta > 0$), we have $\eta_1 > \varepsilon_1 = \hat{\eta}_1$, and $\eta_1 < \varepsilon_1 = \hat{\eta}_1$ if the products are complements ($\beta < 0$). Hence under perfect information, efficient prices are such that the monopoly price equals the duopoly price for good 1.

5.1 Efficient Prices under Symmetric Information

In a duopoly retail market, using Proposition 1 one obtains the optimal prices and access charge, which are given by

$$
\begin{aligned}
p_i^d &= \left(\frac{1}{1+2\lambda}\right)\left[\lambda a_i + (1+\lambda)(c_0+c_i)\right], \quad \text{for } \ i,\, j = 1,2 \ \text{ and } \ i \neq j, \\
\alpha^d &= c_0 + \left(\frac{\lambda}{1+2\lambda}\right)(a_2 - c_0 - c_2).
\end{aligned}
$$

The monopoly price is solved following Proposition 2. This is given by

$$
p_1^m = \left(\frac{1}{1+2\lambda}\right)\left[\lambda a_1 + (1+\lambda)(c_0+c_1)\right].
$$

In this particular case with linear demands, the regulated retail prices of firm 1's product under symmetric information are equal. But this is not necessarily the case under a general demand structure. The welfare differential between the two regimes is given by

$$
\tilde{W}^d(c_2) - \tilde{W}^m = \frac{(b_1 b_2 - \beta^2)(1+2\lambda)(x_2^d)^2}{2b_1}. \tag{30}
$$

From the above we have the socially efficient entry point $c_2^* = (a_2 - c_0) - \frac{\beta}{b_1}(a_1 - (c_0 + c_1))$. Following Proposition 3, if c_2 lies in the interval $[\underline{c}_2, c_2^*]$, then a socially optimal market structure is duopolistic. For $c_2^* < c_2 \leq \bar{c}_2$, the incumbent firm operates as a monopolist in the retail market. Notice that, for $a_1 = a_2$ and $b_1 = b_2 = \beta$ (i.e., when the downstream products are perfect substitutes), we have $c_2^* = c_1$. This implies that, if the products are homogeneous, then firm 2 is allowed to operate in the retail market only if it is more cost-efficient than the incumbent firm.

5.2 Efficient Prices under Asymmetric Information

The first order conditions for the regulator's optimization problem with respect to p_1 and p_2 give rise to the following Ramsey prices:

$$\begin{aligned} p_1 &= \left(\frac{1}{1+2\lambda}\right)[\lambda a_1 + (1+\lambda)(c_0 + c_1)], \\ p_2 &= \left(\frac{1}{1+2\lambda}\right)[\lambda a_2 + (1+\lambda)(c_0 + \hat{c}_2)] - \frac{R(\hat{c}_2)}{1+2\lambda}, \text{ where } R(c_2) = \frac{\int_{\underline{c}_2}^{c_2} G(c_2)dc_2}{G(c_2)}. \end{aligned}$$

The optimal entry cut-off point $\hat{c}_2$ is found by solving the first order condition (28) of the regulator's maximization problem. For linear demands, this is given by

$$(1+\lambda)^2[y - t(\hat{c}_2)]^2 - 2\lambda(1+\lambda)b_1 h(\hat{c}_2)[y - t(\hat{c}_2)] - b_1^2 R(\hat{c}_2)[R(\hat{c}_2) + 2\lambda h(\hat{c}_2)] = 0, \quad (31)$$

where $t(\hat{c}_2) \equiv b_1(\hat{c}_2 - \underline{c}_2)$, and $y \equiv b_1(a_2 - c_0 - \underline{c}_2) - \beta(a_1 - c_0 - c_1)$.

5.3 Optimal Entry

Finally we analyze whether entry is efficient or inefficient compared to the social optimum. Observe that using the value of c_2^* we get $y - t(\hat{c}_2) = b_1(c_2^* - \hat{c}_2)$. Using this in condition (31) and then simplifying it, we get

$$[(1+\lambda)(c_2^* - \hat{c}_2) + R(\hat{c}_2)][(1+\lambda)(c_2^* - \hat{c}_2) - R(\hat{c}_2) - 2\lambda h(\hat{c}_2)] = 0. \quad (31')$$

From (31′) it follows that the optimal $\hat{c}_2$ satisfies any one of the following conditions:

$$\mathscr{Q}_1(\hat{c}_2) \equiv \hat{c}_2 - \frac{R(\hat{c}_2)}{(1+\lambda)} - c_2^* = 0 \tag{32}$$

$$\mathscr{Q}_2(\hat{c}_2) \equiv \hat{c}_2 + \frac{R(\hat{c}_2) + 2\lambda h(\hat{c}_2)}{(1+\lambda)} - c_2^* = 0. \tag{33}$$

Let $\hat{c}_2'$ and $\hat{c}_2''$ be the solutions to $\mathscr{Q}_1(\hat{c}_2) = 0$ and $\mathscr{Q}_2(\hat{c}_2) = 0$, respectively.[9] Clearly, from (32) and (33) it follows that $\hat{c}_2'' < c_2^* < \hat{c}_2'$, and hence the welfare maximizing solution is $\hat{c}_2''$. Then from (33) we have $c_2^* > \hat{c}_2''$. Thus there is "too little entry". For example, consider the following family of distribution functions $\mathscr{G} = \{\{G_k(.)\}_{k\in\mathbf{R},k>-1}\}$ where for any given $k > -1$, $G_k(x) = \left(\frac{x-\underline{c}_2}{\overline{c}_2-\underline{c}_2}\right)^{k+1}$.[10] For any element from this family, $\mathscr{Q}_i(\hat{c}_2) = 0$ has a unique solution for $i = 1,2$. Hence the optimal solution is obtained from $\mathscr{Q}_2(\hat{c}_2) = 0$ and in particular, $\hat{c}_2'' = \underline{c}_2 + \frac{(k+1)(k+2)}{(k+1)(k+3)+2\lambda}(c_2^* - \underline{c}_2) < c_2^*$ given $k > -1$.

6 Concluding Remarks

In this paper we have argued how the traditional Ramsey access pricing rule can be modified when market structure is endogenous. This modification is necessary only when the cost of the entrant is unknown. In this regard we derive modified superelasticities of the retail goods that internalize the impact of the regulatory pricing rule on the entry decision.

Popular belief asserts that access to essential facility should be non-discriminatory. Following this tradition we have designed a non-discriminatory pricing rule and argued that such a pricing rule, when designed by a utilitarian regulator, has a significant impact on the entry decision of the rival firm as the regulator cannot perfectly control the entry into the retail market.

[9] It can be proved that $\mathscr{Q}_i(\hat{c}_2) = 0$ for $i = 1, 2$ will *never* have imaginary conjugate solution(s).
[10] For $k = 0$, $G_0(.)$ is Uniform.

Taking resort to a linear demand system we have shown that there is too little entry compared to the socially efficient entry and this conclusion holds under very general distribution functions of the unknown marginal cost of the entrant.

We assumed that the potential entrant possesses market power instead of being part of a competitive fringe. When the entrant is assumed to be competitive, one can also draw conclusions that are similar to the ones we find here. An interesting extension of the current model would be to consider a partially regulated industry where the regulator only designs the access fee (possibly a two-part tariff), and the firms compete in a Bertrand fashion in the downstream market. A more challenging open question in this context will be to design the regulatory mechanism when it is possible for the regulator to offer a menu of contracts to the entrant.

Appendix A

Proofs of Propositions 1 and 2 First consider the regulator's problem (4) under symmetric information. The first order conditions of this maximization problem can be written as

$$\begin{bmatrix} \eta_1 & -\eta_{21}\left(\frac{p_2 x_2^d}{p_1 x_1^d}\right) \\ -\eta_{12}\left(\frac{p_1 x_1^d}{p_2 x_2^d}\right) & \eta_2 \end{bmatrix} \begin{bmatrix} L_1^d \\ L_2^d \end{bmatrix} = \begin{bmatrix} \frac{\lambda}{1+\lambda} \\ \frac{\lambda}{1+\lambda} \end{bmatrix}$$

Solving the above system of equations and incorporating the fact that $\alpha = p_2 - c_2$ we get (5) and (6).

Now consider the regulator's optimization problem (8) under symmetric information. The first order condition is given by

$$(p_1^m - c_0 - c_1)\frac{\partial x_1^m}{\partial p_1} = -\frac{\lambda}{1+\lambda}x_1^m .$$

Solving the above we get (9).

Proof of Proposition 3 To prove this proposition, let $\tilde{W}^d(c_2)$ and $\tilde{W}^m$ be the maximum values of social welfare in duopoly and monopoly, respectively. Using the Envelope theorem we get

$$\frac{d\tilde{W}^d(c_2)}{dc_2} = -(1+\lambda)x_2^d < 0.$$

The above implies that the function $\tilde{W}^d(c_2)$ is monotonically decreasing with respect to c_2. Notice that $\tilde{W}^m$ does not depend on c_2. Three cases might emerge. (1) Suppose first that $\tilde{W}^d(\underline{c}_2) < \tilde{W}^m$. In this case $c_2^* = \underline{c}_2$. This implies that welfare under monopoly is always higher than that under duopoly, and hence, even the most efficient type of firm 2 is not allowed to enter. Thus, the socially optimal market structure is that the retail market is served only by firm 1. (2) Now suppose that $\tilde{W}^d(\bar{c}_2) > \tilde{W}^m$. In this case $c_2^* = \bar{c}_2$. Then welfare under duopoly is always higher than that under monopoly, and hence, even the least efficient type of firm 2 is allowed to enter. (3) Finally, suppose that $\tilde{W}^d(\bar{c}_2) < \tilde{W}^m < \tilde{W}^d(\underline{c}_2)$. In this case we have $c_2^* \in (\underline{c}_2, \bar{c}_2)$ such that $\tilde{W}^d(c_2^*) = \tilde{W}^m$.

Appendix B

Properties of the Modified Superelasticity We first prove the property that the modified superelasticities can be expressed as a weighted arithmetic mean of own price elasticities and the traditional superelasticities. First, consider the case of firm 1. Its modified superelasticity can be written as

$$
\begin{aligned}
\hat{\eta}_1^G &= \frac{G(\hat{c}_2)x_1^d(\eta_1\eta_2 - \eta_{12}\eta_{21}) + [1 - G(\hat{c}_2)]x_1^m \varepsilon_1 \eta_2}{\bar{x}_1(\bar{\eta}_2 + \bar{\eta}_{12})}, \\
&= \left[\frac{G(\hat{c}_2)x_1^d(\eta_2 + \eta_{12})}{\bar{x}_1(\bar{\eta}_2 + \bar{\eta}_{12})}\right]\hat{\eta}_1 + \left[\frac{(1 - G(\hat{c}_2))x_1^m \eta_2}{\bar{x}_1(\bar{\eta}_2 + \bar{\eta}_{12})}\right]\varepsilon_1, \\
&= [\theta_1(\hat{c}_2)]\,\hat{\eta}_1 + [1 - \theta_1(\hat{c}_2)]\varepsilon_1 .
\end{aligned}
$$

Next consider the modified superelasticity of good 2, which can be written as follows.

$$
\begin{aligned}
\hat{\eta}_2^G &= \left[\frac{G(\hat{c}_2)x_1^d(\eta_1 + \eta_{21})}{\bar{x}_1(\bar{\eta}_1 + \bar{\eta}_{21})}\right]\hat{\eta}_2 + \left[\frac{(1 - G(\hat{c}_2))x_1^m(\varepsilon_1 + \eta_{21})}{\bar{x}_1(\bar{\eta}_1 + \bar{\eta}_{21})}\right]\left(\frac{\varepsilon_1}{\varepsilon_1 + \eta_{21}}\right)\eta_2, \\
&= [\theta_2(\hat{c}_2)]\,\hat{\eta}_2 + [1 - \theta_2(\hat{c}_2)]\delta\,\eta_2,
\end{aligned}
$$

where $\delta = \frac{\varepsilon_1}{\varepsilon_1 + \eta_{21}}$.

Notice that $\theta_i(\hat{c}_2) = 1$ (for $i = 1, 2$) when $\hat{c}_2 = \bar{c}_2$ (i.e., the retail market is a duopoly). When no types of firm 2 are allowed to enter, i.e., $G(.) = 0$, we have $\theta_1(\hat{c}_2) = 0$ and $\hat{\eta}_1^G$ equals ε_1, since this firm is a monopolist in the retail market. In case of firm 2 a similar conclusion can be drawn. As $G(\hat{c}_2)$ approaches zero, the modified superelasticity of firm 2 approaches its price elasticity associated with the duopoly demand, $x_2^d(p_1, p_2)$. Obviously, at $G(.) = 0$, this firm does not supply a positive quantity, and hence, the value of $\hat{\eta}_2^G$ at this point is not well defined.

Next we analyze the behavior of the modified superelasticities with respect to the probability of entry. Notice that, for $i = 1, 2$, $\theta_i(\hat{c}_2)$ is increasing in $G(.)$. Hence,

$$
\begin{aligned}
\frac{\partial\,\hat{\eta}_1^G}{\partial\,G(.)} &\gtreqless 0 \;\text{ as }\; \hat{\eta}_1 \gtreqless \varepsilon_1, \\
\frac{\partial\,\hat{\eta}_2^G}{\partial\,G(.)} &\gtreqless 0 \;\text{ as }\; \hat{\eta}_2 \gtreqless \delta\eta_2.
\end{aligned}
$$

It is easy to show that $\hat{\eta}_1 \gtreqless \varepsilon_1$ and $\hat{\eta}_2 \gtreqless \delta\eta_2$ are equivalent conditions. Notice that

$$\begin{aligned} &\hat{\eta}_1 \gtreqless \varepsilon_1 \\ \Leftrightarrow\ &\eta_1\eta_2 - \eta_{12}\eta_{21} \gtreqless \varepsilon_1(\eta_2 + \eta_{12}), \end{aligned} \tag{34}$$

and

$$\begin{aligned} &\hat{\eta}_2 \gtreqless \delta\eta_2 \\ \Leftrightarrow\ &\frac{\eta_1\eta_2 - \eta_{12}\eta_{21}}{\eta_1\eta_2 + \eta_2\eta_{21}} \gtreqless \frac{\varepsilon_1}{\varepsilon_1 + \eta_{21}} \\ \Leftrightarrow\ &\varepsilon_1(\eta_1\eta_2 - \eta_{12}\eta_{21}) + \eta_{12}(\eta_1\eta_2 - \eta_{12}\eta_{21}) \gtreqless \varepsilon_1(\eta_1\eta_2 + \eta_{21}\eta_2) \\ \Leftrightarrow\ &\eta_{21}(\eta_1\eta_2 - \eta_{12}\eta_{21}) \gtreqless \varepsilon_1\eta_{21}(\eta_2 + \eta_{12}) \\ \Leftrightarrow\ &\eta_1\eta_2 - \eta_{12}\eta_{21} \gtreqless \varepsilon_1(\eta_2 + \eta_{12}). \end{aligned} \tag{35}$$

Finally, notice that $\bar{x}_1\bar{\eta}_{12} = G(\hat{c}_2)x_1^d\eta_{12}$ and $\bar{\eta}_{21} = \eta_{21}$. Hence, if the goods are substitutes (complements), i.e., if $\eta_{ij} > (<) 0$ for $i = 1, 2$, then we have $\bar{\eta}_{ij} > (<) 0$ for $i = 1, 2$. Thus $\hat{\eta}_i < (>) \eta_i$ is equivalent to $\hat{\eta}_i^G < (>) \bar{\eta}_i$ for $i = 1, 2$.

Proof of Proposition 4 First notice that the regulator's objective function (12) is the sum of social welfare under duopoly and that under monopoly. The regulator maximizes this expression subject to (10) and (11), both of which bind at the optimum. Binding (10) defines the optimal entry cut-off $\hat{c}_2$. Hence, a regulatory mechanism (p_1, p_2, α) can equivalently be represented by a mechanism $(p_1, p_2, \hat{c}_2)$. Incorporating the constraints into the objective function (12) we get the expression (13). Define

$$\hat{L}_2 \equiv \frac{p_2 - c_0 - \hat{c}_2}{p_2} \quad \text{and} \quad H(c_2) = \int_{\underline{c}_2}^{c_2} G(x)dx.$$

The first order conditions of the regulator's maximization problem can be written as

$$\begin{bmatrix} -(1+\lambda)\bar{\eta}_1\bar{x_1} & (1+\lambda)\bar{\eta}_{21}\bar{x_2}\left(\frac{p_2}{p_1}\right) \\ (1+\lambda)\bar{\eta}_{12}\bar{x_1}\left(\frac{p_1}{p_2}\right) & -(1+\lambda)\bar{\eta}_2\bar{x_2} \end{bmatrix} \begin{bmatrix} L_1^G \\ \hat{L}_2 \end{bmatrix} = \begin{bmatrix} -\lambda\bar{x_1} - H(\hat{c}_2)\frac{\partial x_2^d}{\partial p_1} \\ -\lambda\bar{x_2} - H(\hat{c}_2)\frac{\partial x_2^d}{\partial p_2} \end{bmatrix}$$

Solving the above system of equations, and using (10) and the expression for $\mu_2(\hat{c}_2)$ we get (21), (22) and (23).

Proof of Corollary 1 This corollary follows directly from the condition (19) and Proposition 4.

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