EFFICIENT ACCESS PRICING AND ENDOGENOUS MARKET STRUCTURE*

Kaniska Dam† Axel Gautier‡ Manipushpak Mitra§

Abstract
We investigate how regulatory mechanisms influence the nature of competition in a network industry. In the downstream segment of the market, the seller of a differentiated retail product competes with an incumbent firm. The incumbent firm is also the owner of the essential input. The regulator cannot observe the costs of the entrant, and to maximize social welfare designs the retail prices and the access charge that the entrant pays to the incumbent. The optimal access charge is a uniform price that respects the criteria of transparency and non-discrimination that are imposed by the competition and regulation directives in most of the countries. We derive new formulas for retail and access prices adhering to the Ramsey rule. Since the competing firm takes the decision to enter following the choice of the regulatory regime, the nature of the retail market competition is endogenous. It can either be served by both the firms, or can have the incumbent as the monopoly supplier of the retail good. (JEL: L51)

1 Introduction

The worldwide privatization wave of the late 20th century made the design of optimal access prices one of the most challenging tasks in the realm of regulation and antitrust. The problem of access pricing aims at fostering competition in industries where competitors do not own the

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†Centro de Investigación y Docencia Económicas, Carretera México-Toluca 3655, Lomas de Santa Fe, 01210 Mexico City, Mexico. E-mail: kaniska_dam@cide.edu
‡Corresponding author. CREPP, HEC-Université de Liège, Bat B31, Boulevard du Rectorat 7, 4000 Liège, Belgium, and CORE, Université Catholique de Louvain, Belgium. E-mail: agautier@ulg.ac.be
§Economic Research Unit, Indian Statistical Institute, 203 B. T. Road, Kolkata 700 108, India. E-mail: mmitra@isical.ac.in
essential inputs of production (bottleneck input, in the jargon of regulation). Examples of such input include local loop (in local and long distance telephone), transmission grid (in electricity generation), pipelines (in natural gas), tracks and stations (in railroad transportation) and local delivery network (in postal services). In many countries a bottleneck input is supplied by a monopolist. Presence of scale economies (due to high fixed network cost) and absence of competing technologies (due to high cost of bypass) are the main reasons for such natural monopolies. In this case the end users of the bottleneck inputs (providers of retail services) pay access charges to cover the fixed cost of the network. Apart from supplying the essential input, if its owner is a competitor in the downstream market, then it is in its natural interests to foreclose this market segment by charging a discriminatory or even a prohibitively high access price. Thus, the regulation of access conditions in such industries is of utmost importance. The statutory directives of the competition and regulation authorities in almost all the countries assert that the access prices must be ‘transparent’ and ‘non-discriminatory’. The first is the requirement that the access price must be purely cost-based. On the other hand, non-discrimination implies that the owner of the network can neither deny access to any competitor, nor practice price discrimination with respect to the competitors’ demand and cost conditions.\(^1\)

This paper considers a model of regulated industry to analyze the one-way access problem. The owner of the network (the incumbent firm) is a vertically integrated firm that faces a potential competitor in the [downstream] retail market for differentiated products (e.g., local calls). The regulator can observe the incumbent’s marginal costs of producing the network and the retail good, but not the marginal cost of production of the entrant’s retail good. The utilitarian regulator designs the retail prices and access charge to maximize social welfare. The access receipts plus a transfer from the regulator reimburse the fixed cost of the network. A high access price deters entry to efficient competitors, whereas a low access price encourages entry to the inefficient types. Thus an optimally chosen access charge is of prime importance in promoting entry. We assume the retail market to be partially regulated in the sense that the regulator fixes the retail prices, but does not control the entry decision. We provide two important results. First, we provide new pricing formulas that adhere to the Ramsey rule with the constraints that the access and retail prices should be uniform prices (that do not depend on the characteristics of the entrant). In our pricing rule, the Lerner index of each retail good is inversely related to its ‘modified’ superelasticity. This implies that the retail prices crucially depend on the nature

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\(^1\)See, for example, the European competition directives on telecommunication (90/388/EEC), electricity (96/92/EC), gas (2003/55/EC), rail (2002/14/EC) and postal services (96/67/EC) that include a ‘non-discrimination’ clause for access charges.
of downstream competition, which is determined by the probability of entry into this segment of the market. We then analyze the behavior of retail prices with respect to the probability of entry. The second is that, as the entry decision follows the design of retail and access prices, the structure of the retail market is endogenous in the sense that the market is served by both the incumbent and the entrant firms (duopoly) with a positive probability and is monopoly with the complementary probability. This is determined by the endogenous cut-off of the entrant’s marginal cost beyond which there is no entry into the retail market. We further show that, under asymmetric information, entry is generally inefficient because the aforesaid cut-off differs from the first-best entry level. We also show that, under linear demands for the retail product, one has “too little” entry compared to socially optimal entry (Proposition 5). The term “too little” entry refers to the fact that the optimal entry cut-off level falls below the socially optimal entry level. This is to say that if the marginal cost of the entrant firm were observable then there should have been more types of this firm competing in the retail market compared to the number of types that actually enter under asymmetric information. Hence, the difference between the socially optimal entry level and the cut-off under asymmetric information is a measure of such type of inefficiency. In our linear demand example, we further show that this inefficiency decreases as the degree of substitutability between the retail products increases.

The economics of access pricing uses two popular approaches: the efficient component pricing rule (ECPR) and the Ramsey rule. The first kind proposes that the access charge should be equal to the opportunity cost that the owner of the network (who also provides retail services) incurs.\(^2\) One consequence of such rule is that the downstream market is served by the incumbent if the entrant is less cost-efficient. Although one objective of pricing by the ECPR is to foster efficient entry, the rule per se is not efficient because it takes into account the private opportunity cost of supplying network, not its social opportunity cost. Ramsey pricing, on the other hand, maximizes social welfare such that the owner of the network breaks even. In a seminal work, Laffont and Tirole (1994) use a mechanism design approach to the access pricing problem, and propose optimal access price according to Ramsey rule when the regulator does not observe the cost conditions of the supplier of the bottleneck input. In this context, the Ramsey rule is modified which is a menu of prices, one for each cost-type. The analysis of Laffont and Tirole (1994) can easily be extended, as done in Lewis and Sappington (1999), to the case where the regulator does not have perfect knowledge of the cost conditions of the entrant(s) in the downstream market. De Fraja (1999) considers a mechanism in which the cost of the entrant

\(^2\)See Baumol (1983); Baumol and Sidak (1994); Economides and White (1995) for analyses and critiques of the ECPR.
is known and that of the incumbent is not known. In this case the optimal retail and access prices are non-linear prices that depend on the marginal cost of the entrant. Often optimality can be achieved by imposing a two-part tariff.

In most of the countries a ‘menu’ of access prices, which is a particular form of non-linear pricing, is considered discriminatory, although it conforms to the requirements of (constrained) efficiency and transparency. The competition directives encourage and often force the network owners to charge a uniform access price in view of promoting competition. Thus, the traditional, mechanism-design approach to regulation under asymmetric information where the entrant faces a menu of type-contingent prices may not conform with the transparency and no-discrimination requirements. Our approach (a uniform access price) aims at maximizing social welfare leaving the entry decision entirely to the competitor in the downstream market. Thus the pricing rule we propose is clearly (constrained) efficient, transparent, non-discriminatory, and makes the market structure endogenous.

As our pricing rule aims at endogenizing the downstream market structure, the sequence that the regulatory mechanism is chosen prior to the entry decision is important. Wallsten (2003) claims that a reverse sequencing creates uncertainty over the regulatory environment that may prevail in future and leads to welfare-reducing under-investment in network. For example, in 1990 the Argentine president Carlos Menem privatized the ENTeL, the country’s public telecom company, which generated much debate regarding its hurried nature. Menem’s administration sold the public company to the northern and the southern companies without establishing a

3 Also see Armstrong, Doyel and Vickers (1996); Laffont and Tirole (2000) for an analysis of Ramsey pricing and its comparison with the ECPR.

4 Discrimination in access is a sensible issue, especially when the access provider offers also competing down-stream services. Whether second degree price discrimination (menu pricing) should be considered as discriminatory is an issue of debate. In 1998, Deutsche Bahn, the German train operator, introduced TPS 98 access tariff, which included two possible payment options for using the rail tracks: a two-part tariff and a flat charge. The Bundeskartellamt, the German Cartel Office, considered this scheme as discriminatory on the grounds that marginal and average prices differ across companies. Following that, Deutsche Bahn replaced this payment scheme by a single tariff (Pittman, 2004). According to Article 82(c) of the European Treaty, the application by a dominant firm of dissimilar trading conditions to equivalent transactions is prohibited if it places some firms at a competitively disadvantageous position. This, per se, does not rule out second degree price discrimination by the access provider. However, the European Commission and the European Court of Justice have always taken a tough stance on discriminatory prices adopted by dominant firms which are not justified by cost saving (Motta, 2004, pp. 499). Since a second degree price discrimination among the different entrant’s types is a potentially unlawful practice under the antitrust laws, we have chosen to focus only on flat/uniform retail and access prices.

5 In the mechanism design approach the downstream market is a duopoly and each cost-type of the competitor pays a different access charge. De Fraja (1999) shows that variations of such pricing are ‘pro-competitive’ when the efficiency difference between the incumbent and the entrant is not too large, even if they may encourage inefficient entry.
credible regulatory regime. Hill and Abdala (1996) have viewed this as a lack to commitment on behalf of the government and claimed the process to be welfare reducing. Thus, the right sequencing of reform may lie in the prior establishment of a well-defined regulatory mechanism, and leaving it to the market forces to decide on the nature of the downstream competition. To this end, our approach is close to the following literature on regulation and market structure. There is a class of models (Auriol and Laffont, 1993; Dana and Spier, 1994; Jehiel and Moldovanu, 2004) which assume that the regulator designs the market structure and selects the firms which are awarded the right to operate in the retail market as a function of their reported costs. Another class of models considers the situation where the market structure is not designed by the regulator though the regulatory environment has a clear influence on the competitors’ behavior, especially its entry decision. Caillaud (1990) considers competition between a regulated network-based firm and a competitive fringe that uses an alternative technology to bypass the existing network. The fringe is active on this market depending on the cost of the alternative technology and the regulated price of the network-based firm. Gautier and Mitra (2008) consider a homogenous product environment where the option to bypass is not available to competitors. Depending on the incumbent’s regulated supply and the access conditions, an entrant may compete in or stay out of the retail market. In their model, entry may not be efficient. Gautier (2007) observes that there is too little entry with both two-part and single tariffs for the access charge, the later generating more entry. Bloch and Gautier (2008) 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 excessive access does not emerge. In all these models, entry decisions are taken once the regulatory mechanism is known but entry itself is not regulated. In that sense, the market structure is endogenous.

This paper considers the above mentioned problem of regulation in a differentiated product industry characterized by one-way access to essential input. The study deals with the design of regulatory mechanism when the regulator cannot observe the cost of the entrant and where the other constraints are transparency (access pricing is cost-based) and non-discrimination (uniform pricing, i.e., all cost-types of the entrant pays the same per unit price). One advantage of such a mechanism design is that it conforms to the directives of the competition and regulation authorities followed by most countries. The sequence of events in our mechanism is in agreement with the one suggested by Wallsten (2003) that minimizes the chance of welfare reducing effects like future under investment in networks. This sequence selection makes the market structure endogenous. However, as is expected, the cost of incorporating all these
realistic features is that the regulatory mechanism is constrained efficient.

2 The Model

We consider an economy with two firms. Firm 1, the incumbent, is a vertically integrated firm which owns a network good that cannot be cheaply duplicated, and produces a retail good/service. 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 each 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 $\alpha$.

The cost parameters $k_0$, $c_0$ and $c_1$ of the incumbent are publicly observable, but the entrant’s marginal cost is private information. The parameter $c_2$ is distributed according to the function $G(c_2)$ over the positive support $[c_2, \bar{c}_2] \subset \mathbb{R}_{++}$. Let $g(c_2)$ be the continuous and differentiable density associated with $G(c_2)$. We assume that $g(c_2) > 0$ for all $c_2 \in [c_2, \bar{c}_2]$. The distribution of $c_2$ is common knowledge.$^6$

We consider a market where the retail prices $p_1$ and $p_2$ and the access charge $\alpha$ are set

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$^6$The assumption that the regulator has prefect knowledge of the technology of the incumbent but not of the entrant may seem unrealistic. The crucial point of our analysis is that the entrant’s marginal cost is unknown to the regulator and that in the optimal mechanism the regulator does not seek to reveal this private information. The assumptions that the regulator knows $c_1$ and the incumbent always produces a retail good make the analysis of the downstream market structure simple in the sense that monopoly involves only the incumbent firm and duopoly involves both of them. Had there been uncertainty over $c_1$ along with $c_2$, then there would have been the additional possibility of zero supply (with no firm producing the retail goods). The assumption that the regulator also knows $k_0$ and $c_0$ may appear to be restrictive too. The kinds of market we have in mind are the utility sectors where the incumbent firm is either public or a recently privatized firm that is the owner of a network good. For example, in 1990, after the privatization of the Mexican public telephone company, Telmex was given such exclusivity right for the initial years. Often such reformatory actions are taken during a gradual privatization process in which the initial phase of divestiture of the state-owned assets to private monopolies is meant to have improved corporate governance prior to opening the market completely to competition. In such situations it is quite natural that the regulator have the perfect knowledge of the cost of the incumbent or at least a correct estimate of it. Since the entrants are new firms into the retail market, it is not too unnatural to assume that the regulator does not know their levels of efficiency due to technological uncertainties.
by a utilitarian regulator.\textsuperscript{7} We adopt the accounting convention that the regulator collects the total sales revenue \((p_1x_1)\) of firm 1, and reimburses the incumbent for incurring the total cost producing the network via a monetary transfer \((t)\) plus the total access receipts \((\alpha x_2)\) paid by the entrant. Since the net profit 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.

Consumers have quasilinear preferences. The consumer surplus from the downstream products is given by \(U(x_1, x_2)\), where \(U\) is the indirect utility function. Demand functions are obtained by maximizing \(U(x_1, x_2)\) net of the total expenditure, \(p_1x_1 + p_2x_2\). 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 \(x_j = 0\). Thus the demand for the retail goods at prices \((p_1, p_2)\) faced by firm 1 is given by

\[
x_1(p_1, p_2) = \begin{cases} 
  x^d_1(p_1, p_2), & \text{if firm 2 enters,} \\
  x^m_1(p_1), & \text{if firm 2 does not enter.}
\end{cases}
\]

The demand faced by firm 2 is \(x_2 = x^d_2(p_1, p_2)\). Let \(\eta_i\) and \(\eta_{ij}\), for \(i, j = 1, 2\), be the own and cross price elasticities of \(x^d_i\), respectively, and let \(\epsilon_1\) be the own price elasticity of \(x^m_1\). 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 events is as follows. Firm 2 learns its marginal cost \(c_2\) privately. Then the regulator sets the regulatory mechanism \((p_1, p_2, \alpha)\). After being offered the mechanism \((p_1, p_2, \alpha)\), firm 2 makes the entry decision. If it decided to enter the retail market, the firms sell quantities \(x^d_i(p_1, p_2)\) for \(i = 1, 2\). Otherwise, firm 1 sells quantity \(x^m_1(p_1)\) 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.

\textsuperscript{7}Regulated retail prices imply that the regulator is assumed to have the entire bargaining power. Although this is an abstraction from the reality, this is to avoid the complications of signaling issues when an informed agent (here, firm 2) is involved in the contract design. Fully regulated retail prices may be justified by the presence of price caps. Regulation via price caps is a common feature in many industries such as telecom and utilities. In 2003, 57 out of 73 US Local Exchange Carriers (LECs) that have reported to the ARMIS database of the Federal Communications Commission were subject to some form of price cap regulation (22 were regulated according to an RPI-X price cap and a further 35 were subject to other retail price controls).
3 Optimal Regulation under Symmetric Information

In this section we assume that $c_2$ is observed by the regulator, and hence the first-best can be achieved. The analysis is done in two steps. First we assume that the downstream market is either served by both the firms, or only by the incumbent. We compute the optimal retail and access prices, and the maximized social welfare in each situation. Then we find a cut-off level of $c_2$ below which entry is socially efficient in the sense that for these values of the entrant’s marginal cost a duopoly retail market generates higher welfare than a monopoly does.

3.1 Duopoly Market Structure

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 $\alpha$. The welfare is defined as the sum of consumer and producer surplus. In order to reimburse firm 1 for providing access to the entrant firm, the regulator must raise the amount $t + k_0 + c_0 (x_1^d + x_2^d) - (p_1 - c_1)x_1^d$ through distortionary taxes. We assume that the regulator faces a shadow cost of public fund $\lambda > 0$. This implies that if the regulator wants to raise 1 unit to reimburse the network owner by taxing the consumers, then they face a loss of $1 + \lambda$ in the consumer surplus. The net consumer surplus thus is given by

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

The gross surplus from consuming the downstream products, $U(x_1^d, x_2^d)$, 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 $\alpha x_2^d$ by the entrant. The sum of these two terms, which is its profit, must be non-negative.

$$\Pi_1^d \equiv t + \alpha x_2^d \geq 0. \quad (2)$$

The net profit of the entrant must also be non-negative, i.e.,

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

\[ V^d(p_1, p_2) + \Pi^d_1(p_1, p_2) + \Pi^d_2(p_1, p_2). \]

Since public funds are costly (\( \lambda > 0 \)), the participation constraint of firm 1 binds at the optimum. Also the access price \( \alpha \) is set to ensure that firm 2 breaks even and the second constraint is satisfied with equality. If one incorporates the above two constraints into the regulator's objective function, then it reduces to

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

which the regulator maximizes by optimally choosing the retail prices \( p_1 \) and \( p_2 \). In the following proposition we describe the optimal mechanism as a solution to the regulator's maximization problem.\(^8\)

**Proposition 1** The optimal regulatory mechanism \((p_1^d, p_2^d, \alpha^d)\) in a duopoly retail market under symmetric information is given by the following conditions:

\[ L_i^d \equiv p_i^d - c_0 - c_i \]

\[ = \frac{\lambda}{1 + \lambda} \frac{1}{\hat{\eta}_i}, \quad \text{for } i = 1, 2, \tag{5} \]

\[ \alpha^d = p_2^d - c_2 = c_0 + \frac{\lambda}{1 + \lambda} \frac{p_2^d}{\hat{\eta}_2}, \tag{6} \]

where \( \hat{\eta}_i \) is the superelasticity of good \( i \) for \( i = 1, 2 \), which is given by

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

The superelasticity of good \( i \) 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 price equal to marginal cost of producing the network and its fixed cost would have been financed

\(^8\) The proofs of all subsequent propositions are in the appendix.
only by transfers \((t = k_0)\). Since public funds are costly, part of the network’s fixed cost is financed directly by the consumers who are charged a higher price. The superelasticities are used to allocate fixed costs among differentiated products in a welfare maximizing way. 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

\[
t + k_0 + c_0 x_1^m - (p_1 x_1^m - c_1 x_1^m).
\]

Hence, the net consumer surplus is

\[
V^m \equiv U(x_1^m, 0) - p_1 x_1^m - (1 + \lambda) (t + k_0 + c_0 x_1^m + c_1 x_1^m - p_1 x_1^m).
\]

(7)

Also in this case, 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 reimbursed only through the 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

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

(8)

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

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

\[
L_1^m = \frac{p_1^m - c_0 - c_1}{p_1^m} = \frac{\lambda}{1 + \lambda} \frac{1}{\varepsilon_1}.
\]

(9)

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.⁹

3.3 Socially Optimum Entry

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 the entrant’s marginal cost, \( c^*_2 \) such that if \( c_2 \) falls below this level then the maximized value of social welfare in a 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 the incumbent.

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 the regulator knows only the distribution function \( G(c_2) \) of the marginal cost of firm 2, not the true value of \( c_2 \). In order to maximize the expected social welfare, the regulator chooses the retail prices and the access charge. The pricing scheme is non-discriminatory in the sense that it cannot depend on the marginal cost of firm 2. After observing the regulatory mechanism, firm 2 takes its entry decision. Hence, the regulator, while

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⁹If the demands are not “too” concave, then at a given price \( p_1 \), \( \eta_1 \geq (\leq) \epsilon_1 \) 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 \( \epsilon_1 \). In our linear demand example in Section 5 we have \( \eta_1 > \hat{\eta}_1 = \epsilon_1 \) for substitutes products, and \( \eta_1 < \hat{\eta}_1 = \epsilon_1 \) for complements.
designing the mechanism, knows that firm 2 may enter the market with some probability. Unlike 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 a positive probability, and only by the incumbent with the complementary probability.

### 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 \( \Pi_d^2 \equiv (p_2 - c_2 - \alpha)x_d^2(p_1, p_2) \geq 0 \). We assume that at the regulated prices \((p_1, p_2)\), firm 2 faces strictly positive demand for its product, i.e., \( x_d^2(p_1, p_2) > 0 \). Now define a cut-off marginal cost of firm 2, \( \hat{c}_2 \) such that \( \Pi_d^2(\hat{c}_2) = 0 \). At prices \((p_1, p_2, \alpha)\), we have \( \partial \Pi_d^2/\partial c_2 < 0 \). 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 probability \( 1 - G(\hat{c}_2) \).

Irrespective of the entry decision of firm 2, the incumbent firm receives the monetary transfer \( t \) from the regulator to reimburse its cost. If firm 2 enters the retail market, only then the incumbent receives the access charge. The participation constraint of firm 1 then implies that the expected profit is non-negative, i.e.,

\[
E \Pi_1 \equiv t + G(\hat{c}_2)\alpha x_d^2(p_1, p_2) \geq 0. \tag{11}
\]

The optimal regulatory mechanism \((p_1, p_2, \alpha)\) results from, subject to (10) and (11), the maxi-
mization of
\[
\int_{\Omega} \left\{ \int_{c_2}^{\hat{c}_2} \left[ U \left( x_1^d(p_1, p_2), x_2^d(p_1, p_2) \right) - p_1 x_1^d(p_1, p_2) - p_2 x_2^d(p_1, p_2) \right] \right. \\
- \left\{ (1 + \lambda) \left( t + c_0 \left( x_1^d(p_1, p_2) + x_2^d(p_1, p_2) \right) + k_0 - (p_1 - c_1) x_1^d(p_1, p_2) \right) \right. \\
+ \left\{ t + \alpha x_2^d(p_1, p_2) \right\} + \{(p_2 - c_2 - \alpha) x_2^d(p_1, p_2)\} \right\} dG(c_2) \\
+ \left[ \int_{c_2}^{\hat{c}_2} \left[ \{U(x_1^m(p_1), 0) - p_1 x_1^m(p_1)\} \right. \\
- \left\{ (1 + \lambda) \left( t + c_0 x_1^m(p_1) + k_0 - (p_1 - c_1) x_1^m(p_1) \right) \right\} + t \right] dG(c_2) \right\} \right\}
\]
(12)

It is easy to check that the above optimization problem is strictly concave. Given (10), the regulator choosing a mechanism \((p_1, p_2, \alpha)\) 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:

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

where \(W^d(p_1, p_2, \hat{c}_2)\) equals \(W^d(p_1, p_2)\) in expression (4) evaluated at \(c_2 = \hat{c}_2\), and \(W^m(p_1)\) is defined by (8). The first term in (13) is the expected social welfare under duopoly evaluated at the marginal 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 that produces the quantity \(x_2^d(p_1, p_2)\) at marginal cost \(c_2\) that is lower than \(\hat{c}_2\). In other words, this is the expected incremental profit accrued to firm 2 from having entered with a cost-type more efficient than \(\hat{c}_2\). With a slight abuse of notations, we denote by \((p_1, p_2, \hat{c}_2)\) or by \((p_1, p_2, \alpha)\) the optimal regulatory mechanism under asymmetric information.

### 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 computed from the expected market demands, and is shown to be 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 expected demands of the retail goods 1 and 2, respectively be

\[ \bar{x}_1(p_1, p_2) = G(\hat{c}_2)x_1^d(p_1, p_2) + [1 - G(\hat{c}_2)]x_1^m(p_1), \]
\[ \bar{x}_2(p_1, p_2) = G(\hat{c}_2)x_2^d(p_1, p_2). \]

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

\[ \bar{\eta}_i = -\frac{\partial \bar{x}_i(p_1, p_2)}{\partial p_i} \frac{p_i}{\bar{x}_i}, \]
\[ \bar{\eta}_{ij} = \frac{\partial \bar{x}_i(p_1, p_2)}{\partial p_j} \frac{p_j}{\bar{x}_i}, \]

for \( i, j = 1, 2 \) and \( i \neq j \). In the following we define the modified superelasticities of the retail products 1 and 2 as

\[ \hat{\eta}_i^G = \frac{\bar{\eta}_i(\bar{\eta}_j \bar{\eta}_{ij} - \bar{\eta}_{ij} \bar{\eta}_{ji})}{\bar{\eta}_i \bar{\eta}_j + \bar{\eta}_i \bar{\eta}_{ij}}, \text{ for } i, j = 1, 2, \text{ and } i \neq j. \]

The above expressions of the modified superelasticities are similar to the superelasticities derived in the case of symmetric information. Under unknown marginal cost of firm 2, the terms \( \eta_i, \eta_{ij} \) and \( \eta_{ji} \) 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 demand elasticities. Therefore, they depend on the entry decision of firm 2 (since \( G(\hat{c}_2) \) is the total measure of the types of firm 2 with marginal cost lower than \( \hat{c}_2 \)). 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 sum of its superelasticity (obtained under symmetric information) and the price elasticity of the monopoly demand. This property is described in the following equation.\(^{10}\)

\[ \hat{\eta}_1^G = \theta_{11}(\hat{c}_2)\hat{\eta}_1 + \theta_{12}(\hat{c}_2)\varepsilon_1, \]
\[ \hat{\eta}_2^G = \theta_{22}(\hat{c}_2)\hat{\eta}_2 + \theta_{22}(\hat{c}_2)\varepsilon_1. \]

The weights \( \theta_{ij}(\hat{c}_2) \), for \( i, j = 1, 2 \), depend on the probability of entry \( G(\hat{c}_2) \). If \( \hat{c}_2 = \bar{c}_2 \), i.e., if all types of firm 2 were allowed to enter the retail market, then we have \( \theta_{11}(\hat{c}_2) = \theta_{21}(\hat{c}_2) = 1 \)

\(^{10}\)The expressions for the weights are given in Appendix C.
and \( \theta_{12}(\hat{c}_2) = \theta_{21}(\hat{c}_2) = 0 \). In this case the expected demand for good \( i \) coincides with its duopoly demand \( x_i^d(p_1, p_2) \) and its modified superelasticity equals its superelasticity \( \hat{\eta}_i \). If no types of firm 2 are allowed entry, i.e., \( \hat{c}_2 = c_0 \), then the demand faced by firm 1 is the monopoly demand, and hence \( \hat{\eta}_i^G \) equals \( \varepsilon_1 \), the own price elasticity associated with \( x_i^m(p_1) \). In this case, firm 2 does not produce, and we have both \( \theta_{21}(\hat{c}_2) \) and \( \theta_{22}(\hat{c}_2) \) are equal to zero.

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 \( i = 1, 2, \)

\[
\frac{\partial \hat{\eta}_i^G}{\partial G(i)} \geq 0 \quad \text{as} \quad \hat{\eta}_i \geq \varepsilon_1.
\]

Hence, the modified superelasticities can either increase or decrease monotonically 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 the probability of entry.\(^{11}\)

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 Optimal Retail and Access Prices

In this subsection we analyze 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 maximizes the expected social welfare.

**Proposition 4** Under asymmetric information, the welfare maximizing prices \((p_1, p_2, \alpha)\) are

\(^{11}\)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.
solutions to the following conditions:

\[ L_1^G \equiv \frac{p_1 - c_0 - c_1}{p_1} = \frac{\lambda}{1 + \hat{\lambda} \cdot \hat{\eta}_1^G}, \]

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

\[ \alpha = p_2 - \hat{c}_2 = c_0 + \frac{\lambda}{1 + \hat{\lambda}} \frac{p_2}{\hat{\eta}_2^G} \cdot \frac{\hat{c}_2 - \mu_2(\hat{c}_2)}{1 + \hat{\lambda}}, \]

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

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 the fact 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.

The above corollary immediately follows from (19). This result implies that if the retail market is either duopoly (with probability of entry equal to 1) or monopoly (with \( G(\hat{c}_2) = 0 \)), then either \( p_1^d \) or \( p_1^m \) is the regulated price, and hence \( L_1^G \) either equals \( L_1^d \) or \( L_1^m \).

The optimal retail price of good 2 is determined from (22). In this expression \( p_2 \) does not depend on the true realization of the marginal cost of the entrant since the term \( c_2 \) cancels out in both sides. This is because the optimal mechanism is constrained to be non-discriminatory. Hence, all types \( c_2 \) face the same retail and access prices, and consequently all the types that find it profitable to enter the downstream market sell the same quantity \( x_2^d \) at the uniform per unit price \( p_2 \). However, the profit level of an entrant is type-contingent and it increases monotonically with its level of cost efficiency. Hence, at the optimal mechanism, the relative price cost margin depends on \( c_2 \), while the mechanism does not. The Lerner index of firm 2 consists of two terms. The first one is a Ramsey like term which is inversely proportional to the modified superelasticity of the product. We call the second one the “impact-of-entry” term. The role of this term becomes more transparent if one re-writes the Lerner index of firm 2 (i.e., condition
(22)) as a ‘virtual’ Lerner index of the marginal entrant in the following way:

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

(24)

where the virtual marginal cost of the marginal entrant can be expressed as the following.\(^{12}\)

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

According to equation (24), the optimal prices are such that, for each product, the Lerner index evaluated at the virtual marginal cost of the marginal entrant is inversely proportional 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 \(\varepsilon_1\), 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 higher probability of entry is associated with a lower (higher) price for 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.

### 4.4 Endogenous Entry

The optimal regulatory mechanism determines \(\hat{c}_2\), the entry cut-off point. Consequently, \(G(\hat{c}_2)\), the fraction of cost-types of firm 2 that enters the downstream market is also determined endogenously. This term is the probability of having a duopoly retail market. In the case of symmetric information, the regulator would have chosen the cut-off point \(c_2^*\) since he could observe the true realization of the entrant’s cost. Under asymmetric information, the regulator cannot ensure a socially optimum entry level as the decision to enter is taken by firm 2, which

\(^{12}\)The logic behind using the virtual marginal cost of the marginal entrant becomes clearer if one considers the change in \(W^d(p_1, p_2, \hat{c}_2)\) with respect to a change in \(\bar{x}_2\) in the objective function (13), which is given by

$$\frac{\partial W^d(p_1, p_2, \hat{c}_2)}{\partial \bar{x}_2} = (1 + \lambda)(p_2 - c_0 - z(\hat{c}_2)).$$
follows the choice of the regulatory mechanism. The optimal entry is given by the following first order condition of the maximization problem in (13) with respect to \( \hat{c}_2 \).

\[
g(\hat{c}_2)W^d(p_1, p_2, \hat{c}_2) - \lambda G(\hat{c}_2)x^d_2(p_1, p_2) = g(\hat{c}_2)W^m(p_1).
\]  

(25)

To determine the optimal entry cut-off, the expected marginal gain from letting a cost type in the interval \( [\hat{c}_2, \hat{c}_2 + \epsilon] \), where \( \epsilon > 0 \) but infinitesimally small, enter the downstream market must be equal to the marginal gain from not allowing this type to enter the market. Consider equation (13). The first and third terms together are the expected benefits from duopoly conditional on entry (i.e., benefits evaluated at \( c_2 \leq \hat{c}_2 \)). And the second term is the expected benefit from monopoly [that has a probability \( 1 - G(\hat{c}_2) \)]. Thus, the left hand side of the above equation is the incremental expected benefit from duopoly if one increases the entry cut-off \( \hat{c}_2 \) by a small amount, and the right hand side represents the expected marginal benefit from prohibiting this type to enter. From the above equation it is easily seen that there is no guarantee of having \( \hat{c}_2 = c^*_2 \). In this case there is inefficient entry as firm 2’s decision may as well differ from the social optimum. Two forms of such inefficiency may emerge: “excess entry” if \( \hat{c}_2 > c^*_2 \), and “too little entry” if \( \hat{c}_2 < c^*_2 \).\(^{13}\) Consider the latter type. If \( \hat{c}_2 \) falls below \( c^*_2 \), then it would have been socially desirable to let all cost types of firm 2 in the interval \( \in [\hat{c}_2, c^*_2] \) to enter the market. But, given the optimal regulatory mechanism, these types do not enter since they do not find it profitable to do so. Thus, \( c^*_2 - \hat{c}_2 \) can be thought of as a measure of this type of inefficiency. In the next section we show how entry inefficiency is related to the degree of product differentiation in the retail market.

## 5 Optimal Regulation with Linear Demands

Throughout this section 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

\(^{13}\)In a related work, Gautier and Mitra (2008) show that if the incumbent and entrant produce homogenous goods then, under asymmetric information, entry is generically inefficient and that both types of inefficiencies are possible.
(1984), we assume quadratic utility function of the following form.\(^{14}\)

\[
U(x_1, x_2) = (x_1 + x_2) - \frac{1}{2} (x_1^2 + x_2^2) - \beta x_1 x_2.
\] (26)

The parameter \(\beta\) represents the degree of substitutability between the two goods with \(\beta \in (-1, 1)\). In particular we assume that the goods are imperfect substitutes, that is \(\beta \in (0, 1)\). Thus, higher values of \(\beta\) implies that the degree of substitutability is higher across goods. We also assume that \(c_0 + c_1 < 1\), otherwise firm 1 would incur a loss.

When the retail market is served by both the firms, the first order conditions of the consumer’s optimization problem give rise to the following inverse demand functions.

\[
p_1(x_1, x_2) = 1 - x_1 - \beta x_2,
\]

\[
p_2(x_1, x_2) = 1 - x_2 - \beta x_1.
\]

The direct demands can be derived from the above inverse demand functions.

\[
x_1^d(p_1, p_2) = \frac{1 - p_1 + \beta p_2}{1 + \beta},
\]

\[
x_2^d(p_1, p_2) = \frac{1 - p_2 + \beta p_1}{1 + \beta}.
\]

For a monopoly retail market, we have \(x_2 = 0\), and hence the consumer surplus is given by

\[
U(x_1, 0) = x_1 - \frac{1}{2} x_1^2,
\]

which gives rise to the following inverse and direct demand functions,

\[
p_1(x_1) = 1 - x_1 \implies x_1^m(p_1) = 1 - p_1.
\]

For substitute products (\(\beta \in (0, 1)\)), we have \(\eta_1 > \epsilon_1 = \hat{\epsilon}_1\), and \(\eta_1 < \epsilon_1 = \hat{\epsilon}_1\) if the products are complements (\(\beta \in (-1, 0)\)). Hence under perfect information, efficient prices are such that the monopoly price equals the duopoly price for good 1.

\(^{14}\)Our results remain qualitatively unchanged if we assume \(U(x_1, x_2) = a_1 x_1 + a_2 x_2 - \frac{1}{2} (b_1 x_1^2 + b_2 x_2^2) - \beta x_1 x_2\). We take \(a_1 = a_2 = b_1 = b_2 = 1\) for the sake of simplicity.
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

\[ p_i^d = \left( \frac{1}{1+2\lambda} \right) [\lambda + (1+\lambda)(c_0+c_i)], \text{ for } i = 1, 2 \]

\[ \alpha^d = c_0 + \left( \frac{\lambda}{1+2\lambda} \right) (1-c_0-c_2). \]

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

\[ p_{1m} = \left( \frac{1}{1+2\lambda} \right) [\lambda + (1+\lambda)(c_0+c_1)]. \]

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

\[ \tilde{W}^d(c_2) - \tilde{W}^m = \frac{1}{2} (1 - \beta^2) (1 + 2\lambda) \left[ x_2^d \left( p_1^d, p_2^d \right) \right]^2. \] \( (27) \)

From the above we find the socially efficient entry point, which is given by

\[ c_2^* = (1 - \beta)(1 - c_0) + \beta c_1. \] \( (28) \)

Following Proposition 3, if \( c_2 \) lies in the interval \([c_2, c_2^*]\), 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, if \( \beta = 1 \), i.e., if the downstream products are perfect substitutes, then \( c_2^* = c_1 \). 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. The corresponding pricing rule then is similar to the one computed under the ECPR. If there is no uncertainty over the cost of production of the incumbent, then the main goal the regulator pursues is the efficiency of entry. Thus, the optimal pricing must reflect some essence of the ECPR.\(^{15}\)

\(^{15}\)Notice that, even under the first-best, the applicability of the ECPR is not straightforward if the products are not perfect substitutes. See Armstrong, Doyle and Vickers (1996) for pricing under the ECPR with differentiated products.
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:

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

The optimal entry cut-off point $\hat{c}_2$ is found by solving the first order condition (25) of the regulator’s maximization problem.

5.3 Optimal Entry

Finally, we analyze whether entry under asymmetric information is inefficient compared to the social optimum. Using equation (25) and then simplifying it, we get

\[ [(1+\lambda)(\hat{c}_2^* - \hat{c}_2) + R(\hat{c}_2)][(1+\lambda)(\hat{c}_2^* - \hat{c}_2) - R(\hat{c}_2) - 2\lambda h(\hat{c}_2)] = 0, \]

where $h(c_2) = G(c_2)/g(c_2)$. From (29) it follows that the optimal $\hat{c}_2$ satisfies any one of the following conditions:

\[ \mathcal{Q}_1(\hat{c}_2) \equiv \hat{c}_2 - \frac{R(\hat{c}_2)}{1+\lambda} - c_2^* = 0 \]
\[ \mathcal{Q}_2(\hat{c}_2) \equiv \hat{c}_2 + \frac{R(\hat{c}_2) + 2\lambda h(\hat{c}_2)}{1+\lambda} - c_2^* = 0. \]

Let $\hat{c}_2$ and $\hat{c}_2'$ be the solutions to $\mathcal{Q}_1(\hat{c}_2) = 0$ and $\mathcal{Q}_2(\hat{c}_2) = 0$, respectively.\(^\text{16}\) Clearly, from (30) and (31) it follows that $\hat{c}_2 < c_2^* < \hat{c}_2'$, and hence the welfare maximizing solution is $\hat{c}_2$, which implies that $c_2^* > \hat{c}_2$. The above is summarized in the following proposition.

**Proposition 5** When surplus function is quadratic and is given by (26), then the optimal regulation under asymmetric information implies that there is “too little entry” into the downstream market.

\(^{16}\)It can be proved that $\mathcal{Q}_i(\hat{c}_2) = 0$ for $i = 1, 2$ will never have imaginary conjugate solution(s).
Having “too little entry” in the downstream segment is inefficient. If the marginal cost of the entrant could be observed, then efficiency would demand that all cost-types of firm 2 below $c^*_2$ should have entered the market. Thus, the difference $c^*_2 - \hat{c}_2$ measures the extent of inefficiency as far as entry is concerned. On what does inefficiency depend? In the following proposition we show that, for a given family of distribution functions, such inefficiency reduces as the degree of substitutes increases. Consider the following family of distribution functions, $\mathcal{G} = \{\{G_k(.)\}_{k \in \mathbb{R}, k > -1}\}$, where $G_k(.)$ is given by

$$G_k(x) = \left(\frac{x - \underline{c}_2}{\overline{c}_2 - \underline{c}_2}\right)^{k+1}, \text{ for any } k > -1. \quad (32)$$

Notice that $G_k(.)$ is Uniform for $k = 0$. For any element from this family, $\mathcal{Q}_i(\hat{c}_2) = 0$ has a unique solution for $i = 1, 2$. Hence the optimal solution is obtained from $\mathcal{Q}_2(\hat{c}_2) = 0$, which is given by

$$\hat{c}_2 = \delta c^*_2 + (1 - \delta)\underline{c}_2 < c^*_2, \text{ where } \delta = \frac{(1 + \lambda)(k + 1)(k + 2)}{(k + 3)(\lambda + (1 + \lambda)(k + 1))} < 1. \quad (33)$$

The following proposition describes the relationship between entry inefficiency and product substitutability.

**Proposition 6** For the quadratic surplus function given by (26) and for the family of distribution functions given by (32), the inefficiency of entry in the downstream market decreases as the degree of substitution increases.

When products become more similar two effects are at work that reduces the gap between $c^*_2$ and $\hat{c}_2$. If the regulator could observe the marginal cost of the entrant, then he would not have allowed high values of marginal cost to enter the market as producing at a higher marginal cost is detrimental to social welfare. This can be done because higher degree of substitution implies the consumers can more easily switch to firm 1. As a matter of fact, had the product been perfect substitutes this inefficiency is measured by the gap between firm 1’s marginal cost and the marginal entrant’s marginal cost, i.e., by $c_1 - \hat{c}_2$. On the other hand, under asymmetric information when firm 2 decides to enter with a higher marginal cost, the price of its product goes up. In spite of this price rise, higher cost-types of firm 2 find it profitable to enter the retail market as it is relatively easier to steal business from the incumbent firm due to greater product substitutability.
6 Conclusions

We have shown that the way in which a utilitarian regulator designs the retail and access prices influences significantly the nature of competition in the downstream segment of a network industry. When the production technology of the entrant is unknown to the regulator, the regulatory mechanism effectively selects a cut-off in the interior of the whole range of admissible values of the marginal cost of the entrant, below which all types of firm 2 enters the market. In other words, the endogenously determined cumulative probability at this cut-off becomes the probability of having a duopoly retail market. This endogenous entry decision thus must be taken into account while designing the optimal retail and access prices in the previous stage of the game. The optimal prices are modified Ramsey prices that are functions of the probability of entry. It is often asked whether regulation is a substitute for market competition. In this paper we show that the regulator may fine-tune the nature of downstream competition by using modified Ramsey prices that, in principle, does not discard a monopolistic retail market which is served only by the incumbent firm. We further show that the entry under asymmetric information is almost always inefficient, and that the degree of entry inefficiency is decreasing in the degree of product substitutability with mild restrictions on the demand and the distribution functions.

The main focus of the current paper is on the design of optimal regulatory mechanism when the regulator cannot observe the entrant’s cost of production. Two competing mechanisms could have been used in this situation. In one mechanism, the regulator may have used a type-dependent non-linear pricing scheme in which all cost-types of the competitor are allowed to enter the retail market and the optimal access charge is an increasing function of the cost-inefficiency of the entrant. Such mechanisms are based on the so-called ‘revelation principle’ (Baron and Myerson, 1982). In the other mechanism (the one we consider), the regulator is constrained to offer a uniform pricing rule that discourages the highly inefficient types to enter the market, but treats equally the types of the competitor that are willing to serve the downstream market. Both approaches lead to optimal prices that are in conformity with the Ramsey rule. In the current work we do not intend to rank these two mechanisms with respect to some normative criteria. The regulator’s maximization problems the two mechanisms are different with a different set of constraints. We consider the second kind simply because a non-linear pricing is often viewed as a discriminatory practice by the regulation and competition authorities.

In the current paper the optimal retail and access prices are modified Ramsey prices, which
overcomes the pitfall of pricing based on a mechanism design approach in the sense that highly inefficient entrants are not allowed to provide downstream services. Nevertheless, entry is inefficient in the sense that [in the linear demand case] there should have been more cost-types of the entrant firm had the marginal cost of the entrant been observed by the entrant. Following the terminology coined by De Fraja (1999), our regulatory mechanism is ‘pro-competitive’ in the sense that if the regulator cannot observe the marginal cost of the competitor in the retail market, then he does not post an access price which is too high to foreclose the market to the entrant. In other words, the mechanism induces a duopoly retail market with a positive probability. As efficiency and endogeneity of the market competition are the main concerns of our approach to the pricing of access to bottleneck inputs, the optimal pricing rule has some flavor of the ECPR. We improve upon the ECPR in the following ways: (a) our rule is efficient because it maximizes the expected social welfare by taking into account the social opportunity cost of network provision (the shadow cost of public fund influences the pricing rules), and (b) our access pricing formula can be implemented in a second-best world with differentiated products, a situation in which the use of the ECPR would have been inappropriate.

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

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

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).

Appendix B: Proof of Proposition 3
To prove this proposition, let $\tilde{W}^d(\tilde{c}_2)$ and $\tilde{W}^m$ be the maximum values of social welfare respectively under duopoly and monopoly. Notice that $\tilde{W}^d(\tilde{c}_2)$ is continuous in $c_2$. Using the Envelope theorem we get

$$\frac{d\tilde{W}^d(c_2)}{dc_2} = -(1+\lambda)x^d_2 < 0,$$

which 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 $\tilde{W}^d(\tilde{c}_2) < \tilde{W}^m$. In this case $c^*_2 = \tilde{c}_2$. 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 the retail market. Thus, the socially optimal market structure is that the downstream market is served only by firm 1. (2) Now suppose that $\tilde{W}^d(\tilde{c}_2) > \tilde{W}^m$. In this case $c^*_2 = \tilde{c}_2$. In this case 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 $\tilde{W}^d(\tilde{c}_2) = \tilde{W}^m < 0$ and $\tilde{W}^m - \tilde{W}^d(\tilde{c}_2) > 0$. Thus, the intermediate value theorem implies that there exists $c^*_2 \in (\tilde{c}_2, \hat{c}_2)$ such that $\tilde{W}^d(c^*_2) = \tilde{W}^m$.

**Appendix C: Properties of the Modified Superelasticity**

We first prove the property that the modified superelasticity of each retail product can be expressed as a weighted sum of the price elasticity of the monopoly demand and the traditional superelasticity. First, consider the case of firm 1. Its modified superelasticity can be written as

$$\hat{\eta}_1^G = \frac{G(\hat{c}_2)x^d_1(\eta_1 + \eta_2) + [1 - G(\hat{c}_2)]x^m_1\eta_1}{\bar{x}_1(\eta_2 + \eta_{21})},$$

$$= \left[ \frac{G(\hat{c}_2)x^d_1(\eta_2 + \eta_{21})}{\bar{x}_1(\eta_2 + \eta_{21})} \right] \hat{\eta}_1 + \left[ \frac{(1 - G(\hat{c}_2))x^m_1\eta_2}{\bar{x}_1(\eta_2 + \eta_{21})} \right] \epsilon_1,$$

$$= \theta_{11}(\hat{c}_2)\hat{\eta}_1 + \theta_{12}(\hat{c}_2)\epsilon_1.$$

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

$$\hat{\eta}_2^G = \left[ \frac{G(\hat{c}_2)x^d_2(\eta_1 + \eta_{21})}{\bar{x}_1(\eta_1 + \eta_{21})} \right] \hat{\eta}_2 + \left[ \frac{(1 - G(\hat{c}_2))x^m_2(\epsilon_1 + \eta_{21})}{\bar{x}_1(\eta_1 + \eta_{21})} \right] \eta_2,$$

$$= \theta_{21}(\hat{c}_2)\hat{\eta}_2 + \theta_{22}(\hat{c}_2)\epsilon_1,$$

Notice that $\theta_{ii}(\hat{c}_2) = 1$ (for $i = 1, 2$) when $\hat{c}_2 = \tilde{c}_2$ (i.e., the retail market is a duopoly). At this value of $\hat{c}_2$ the modified superelasticities coincide with the traditional superelasticities. When no types of firm 2 are allowed to enter, i.e., $G(.) = 0$, we have $\theta_{11}(\hat{c}_2) = 0$ and $\hat{\eta}_1^G$ equals $\epsilon_1$ since
this firm is a monopolist in the retail market. Obviously, at \( G(.) = 0 \), this firm does not supply a positive quantity, and hence the value of \( \hat{\eta}_2^G \) is zero at this point.

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,

\[
\frac{\partial \hat{\eta}_1^G}{\partial G(.)} \geq 0 \quad \text{as} \quad \hat{\eta}_1 \geq \varepsilon_1, \\
\frac{\partial \hat{\eta}_2^G}{\partial G(.)} \geq 0 \quad \text{as} \quad \hat{\eta}_2 \geq \delta \eta_2.
\]

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

\[
\hat{\eta}_1 \geq \varepsilon_1 \quad \Leftrightarrow \quad \eta_1 \eta_2 - \eta_{12} \eta_{21} \geq \varepsilon_1 (\eta_2 + \eta_{12}), \quad (34)
\]

and

\[
\hat{\eta}_2 \geq \delta \eta_2 \\
\Leftrightarrow \quad \frac{\eta_1 \eta_2 - \eta_{12} \eta_{21}}{\eta_1 \eta_2 + \eta_{12} \eta_{21}} \geq \frac{\varepsilon_1}{\varepsilon_1 + \eta_{21}} \\
\Leftrightarrow \quad \varepsilon_1 (\eta_1 \eta_2 - \eta_{12} \eta_{21}) + \eta_{12} (\eta_1 \eta_2 - \eta_{12} \eta_{21}) \geq \varepsilon_1 (\eta_1 \eta_2 + \eta_{12} \eta_{21}) \\
\Leftrightarrow \quad \eta_{21} (\eta_1 \eta_2 - \eta_{12} \eta_{21}) \geq \varepsilon_1 \eta_{21} (\eta_2 + \eta_{12}) \\
\Leftrightarrow \quad \eta_1 \eta_2 - \eta_{12} \eta_{21} \geq \varepsilon_1 (\eta_2 + \eta_{12}). \quad (35)
\]

Finally, notice that \( \bar{x}_1 \bar{\eta}_{12} = G(\hat{c}_2) x_1 \bar{\eta}_{12} \) 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 \( \hat{\eta}_i \) is equivalent to \( \hat{\eta}_i^G \) for \( i = 1, 2 \).

**Appendix D: 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 \((p_1, p_2, \alpha)\) 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 
\[ \hat{L}_2 = \frac{p_2 - c_0 - \hat{c}_2}{p_2} \quad \text{and} \quad H(c_2) = \int_{c_2}^{c^2} G(x)dx. \]

The first order conditions of the regulator’s maximization problem can be written as
\[
\begin{bmatrix}
- (1 + \lambda) \hat{\eta}_1 \hat{x}_1 & (1 + \lambda) \hat{\eta}_{21} \frac{p_2}{p_1} \\
(1 + \lambda) \hat{\eta}_{12} \hat{x}_1 & -(1 + \lambda) \hat{\eta}_2 \hat{x}_2
\end{bmatrix}
\begin{bmatrix}
L_1^G \\
L_2^G
\end{bmatrix}
= \begin{bmatrix}
- \lambda \hat{x}_1 - H(\hat{c}_2) \frac{\partial \hat{c}_2}{\partial p_1} \\
- \lambda \hat{x}_2 - H(\hat{c}_2) \frac{\partial \hat{c}_2}{\partial p_2}
\end{bmatrix}
\]

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

**Appendix E: Proof of Corollary 1**

From Proposition 4 we have
\[ L_1^G = \frac{\lambda}{1 + \lambda} \hat{\eta}_1^G, \]

Combining the above with the fact that \( \hat{\eta}_1^G = \theta_1 \hat{\eta}_1 + (1 - \theta_1)\varepsilon_1 \), we get
\[ L_1^G = \frac{\lambda}{1 + \lambda} \frac{1}{\theta_1 \hat{\eta}_1 + (1 - \theta_1)\varepsilon_1} = \frac{1}{\frac{\varepsilon_1}{L_1^G} + \frac{1 - \theta_1}{L_1^G}}. \]

This proves the corollary.

**Appendix F: Proof of Proposition 6**

Given the distribution function \( G_k(c_2) \), we can compute the following.
\[ R_k(c_2) = \frac{H_k(c_2)}{G_k(c_2)} = \frac{c_2 - c_k}{k + 2}, \]
\[ h_k(c_2) = \frac{G_k(c_2)}{g_k(c_2)} = \frac{c_2 - c_k}{k + 1}. \]

Substituting the above in equation (33) we get
\[ \hat{c}_2 = \frac{(1 + \lambda)(k + 1)(k + 2)}{(k + 3)[\lambda + (1 + \lambda)(k + 1)]}(c_2^* - \zeta_2) + \delta(c_2^* - \zeta_2) + \zeta_2 = \delta c_2^* + (1 - \delta)\zeta_2. \]
Hence, from the above we have

\[ c_2^* - \hat{c}_2 = (1 - \delta)(c_2^* - \hat{c}_2) = (1 - \delta)((1 - \beta)(1 - c_0) + \beta c_1 - \hat{c}_2), \]

\[ \Rightarrow \frac{d(c_2^* - \hat{c}_2)}{d\beta} = -(1 - c_0 - c_1)(1 - \delta) < 0, \]

given that \( 1 - c_0 - c_1 > 0 \). This completes the proof of the proposition.

References


