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Incomplete Regulation, Competition and Entry in Increasing Returns to Scale Industries*

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Abstract

The paper analyzes the effects of liberalization in increasing-returns-to-scale industries. It determines the optimal regulation of an incumbent competing with an unregulated strategic competitor, when public funds are costly. The model reveals the trade-off between productive and allocative efficiency. Moreover, the welfare gains from liberalization, as compared with regulated monopoly, are a non-monotonic function of the cost of public funds. Finally, in the case of severe governmental cash constraints, incomplete regulation may dominate the full regulation of duopoly.
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1. Introduction

Over the last 25 years many regulated markets have been reformed, both in developed and developing countries. Technological change and growing dissatisfaction with the performance of regulated monopolies led to the introduction of pro-competitive reforms. We refer to this process of market opening as *liberalization*[1] and, in this context, analyze the optimal regulation of an incumbent exposed to unregulated competition. This is particularly relevant in the context of regional integration, such as in the European Union, where EC legislation prescribes the progressive opening of formerly-regulated monopolies to competition. Other regions have similarly promoted market integration in regulated markets (examples are the experiences of energy market integration in Latin America, East Asia, and West and South Africa). One important feature of these markets is that, due to residual increasing returns to scale and incumbency advantages, they tend to stay concentrated and national leaders remain dominant. For this reason, regulation is required even after liberalization. Often this regulation is *incomplete* (or *asymmetric*): the regulator directly influences the operations of the incumbent, while competitors are more-lightly regulated (or even unregulated). This can occur for many reasons. In many cases the incumbent is subject to additional requirements to correct for the consequences of market power (this is common in both the electricity and telecommunications industries) or because it is the universal service provider (universal service obligations are usually contracted with incumbent firms on a long-term basis). In addition, incomplete regulation may emerge because regulators are not able to extend effective regulatory control over large multinational firms (especially in developing countries). Finally, regulated firms may be exposed to competition from unregulated (or less-regulated) producers who use alternative technologies (obvious examples here are rail and road, high-speed railways and airlines, and fixed-line operators and mobile or internet providers).

Empirical work in this area has attempted to measure the impact of increasing competition in regulated markets. Much of this agrees that greater competition induces greater efficiency (see for example the cross-country analysis in Boylaud and Nicoletti, 2000, regarding telecommunications, Pollit, 1995, for electricity, and Wilson, 1997 and Pollit and Smith, 2001 for railways in the US and UK respectively). The impact of competition on prices is far less clear. Hausman, Leonard and Sidak (2002) analyze the entry of the Bell Companies into the US long-distance telecommunication market, and find that increased competition was associated with a lower per-minute price but a higher monthly fee (with the net effect reducing the annual bill of the average consumer). In the case of electricity, empirical evidence does not suggest that liberalization reduces prices. There are some positive results (Steiner, 2001) but many are negative (Green and Newbery in Helm and Jenkinson, 1998, Domah and Pollit, 2001, Zhang, Parker and Kirkpatrick, 2002, and Hattori and Tsutsui, 2004). Overall, pro-competitive reforms seem to increase efficiency but do not necessarily yield lower prices. The broad welfare consequences of these reforms are then not easy to establish.

In what follows we consider the effects of liberalization in an incomplete-regulation framework under yardstick competition. The theoretical benefits of yardstick competition have

[1] In contrast, reforms involving a change of ownership are referred to as *privatization.* The question of ownership, which has been widely studied in the literature, is not explicitly considered here. Examples of surveys of theoretical and empirical work in this area are Shleifer (1998) and Meggison and Netter (2001).

been analyzed in the existing literature, starting with Shleifer (1985). Yardstick competition has been applied by regulators in a number of different industries, for example, in the context of hospital regulation in many countries, following the example of the American Medicare system, as well as bus transportation in Norway and water utilities in the UK. Our model shows how the presence of unregulated competitors may help to regulate producers via yardstick competition. Although this possibility has not received much attention, some empirical evidence along these lines has been documented in Bhaskar, Gupta and Khan (2006), who consider the yardstick effect of the partial privatization of the Bangladeshi jute industry.
We assume that the regulator controls the production of the regulated firm and sets some regulatory instrument (a tax or transfer), but that public funds are costly. We show that yardstick competition helps to reduce rent-seeking behavior by the regulated firm. However, in the presence of costly public funds, competition, via business stealing, complicates the regulatory task. The shadow cost of public funds plays an important role, because it is related to the weight put on the incumbent's profit in the social welfare function. Our model captures in a reduced form the idea that the operating profits of the regulated incumbent are socially valuable, because they help to reduce distortionary taxation.[2] For this reason, the welfare gains from liberalization will depend in a non-trivial way on the cost of public funds.

The main results of the paper are as follows. Consistent with the empirical evidence, we find that the introduction of competition does not always reduce prices. More precisely, for a relatively low value of the cost of public funds, we find a trade-off between productive and allocative efficiency. With a higher cost of public funds, the rent-reducing effect of competition becomes more important and competition always reduces prices. Moreover, we reveal a non-monotonic relationship between the welfare gains from liberalization and the cost of public funds. These welfare gains are robust: incomplete regulation may even dominate the full regulation of a duopoly. This occurs in the case of severe government cash constraints.

1.1 Relationship to the literature

The virtues of the two pure models of monopoly regulation and perfect competition are well understood and appreciated. However, the conditions under which regulated supply turns out to be preferable to unregulated competition in concentrated markets are less clear (Armstrong and Sappington, 2006). In particular Armstrong and Sappington (2005) point out that "*unfettered competition can complicate regulatory policy by undermining preferred pricing structures*", which is a challenge to taxation by regulation. Our

[2]For simplicity, we can think of the revenue of a public or mixed incumbent. However, the model is also consistent with the imposition of taxes on the rents made by private firms. Incumbents are indeed often vertically and/or horizontally integrated with firms operating in non-competitive markets, and their operating profits may help to cross-subsidize non-competitive activities (e.g. infrastructure investment and universal service obligations). A reduction in the incumbent's profit may thus undermine taxation by regulation. Moreover, governments can in general tax domestic firms more easily than foreign firms. Rent extraction does not apply to the same extent to domestic and foreign firms as the latter do not report most of their profits locally.

goal here is to present a formal analysis of this problem. In this respect, our work is related to Auriol and Picard (2009), who show that countries' budgetary conditions can influence their optimal privatization policies. We here extend this analysis to monopoly deregulation.

Our analysis of the welfare effects of yardstick competition, is also related to that in Auriol and Laffont (1993), who consider optimal duopoly regulation in a fully-regulated market. However, we here consider the case of incomplete regulation, which is realistic in many liberalized markets. We also compare our results to theirs, showing that incomplete regulation might be preferred to a fully-regulated market in the case of severe governmental cash constraints.

Our results regarding the impact of competition on prices can be compared to those in Laffont and Tirole (1993) and De Fraja (1997). These latter show that, while competition increases variety, it also leads to higher optimal prices than those under monopoly. We equally have some cases in which competition raises prices, but show that in an oligopolistic context this does not reflect partial substitution, but rather a more general trade-off between productive and allocative efficiency.

The work of Caillaud (1990) is probably the closest to the analysis presented here. He considers competition between a dominant regulated firm and an unregulated fringe under asymmetric information and cost correlation. We here use a stochastic structure inspired by Auriol and Laffont (1993) to extend his analysis to the relevant case of partial cost correlation and introduce yardstick competition. Moreover, contrary to Caillaud (1990) and most of the existing literature (with the noticeable exception of Biglaiser and Ma, 1995), we consider a competitor with market power rather than a non-strategic competitive fringe.

The results we obtain are also to an extent reminiscent of those in the literature on mixed markets (Beato and Mas-Colell, 1984, Vickers and Yarrow, 1988, Cremer, Marchand and Thisse, 1989, 1991, and De Fraja and Delbono, 1989). However, contrary to this literature, we do not assume any exogenous differences between the public and private competitors. The cost disadvantage of the regulated firm is endogenized, and is shown to derive from the rent-seeking behavior of the regulated firm in the presence of asymmetric information.

Finally, Aubert and Pouyet (2004, 2006) consider the possibility of collusion in incompletely-regulated markets.[3] The relationship between collusion and the optimal enforcement of competition policy is beyond the scope of the present paper. We will refer to their work for antitrust issues and related distortions, which do not however change the main insights of our paper (see Sections 4 and 5 below).

1.2 Plan of the paper

The paper proceeds as follows. In Section 2 the model and the resulting optimal price, quantities and market structure are described. Section 3 then presents the welfare analysis, comparing regulated monopoly to liberalization under incomplete regulation, and Section 4 considers the issue of excess entry. Section 5 then compares incomplete

[3] Tangeras (2002) considers the case of collusion under yardstick competition in a complete-regulation framework à la Auriol and Laffont (1993). In this case, the collusion-proof contract introduces an additional distortion which partly reduces the benefits of yardstick competition.

regulation to full duopoly regulation. Last, Section 6 concludes.

2. The model

There are two firms, indexed 1 and 2, with firm 1 being the incumbent. The quantity produced by the incumbent is determined by a regulator,[4] who also sets a regulatory instrument of τ (a tax or transfer). Firm 2, the entrant, is a fully-unregulated competitor. For simplicity, we can think of the national firm being public or mixed. However, asymmetric regulation is a relevant framework even for privatized firms in many liberalized markets, as explained in Section 1. The regulator acts as a Stackelberg leader via the quantity produced by Firm 1. Firm 2 is a Stackelberg follower, and maximizes profit by choosing quantity q_2 after q_1 has been determined.[5] The cost functions of the two firms are as follows:

$$C_i(q_i) = \theta_i q_i + k$$

where the index $i \in \{1, 2\}$ refers to the two firms, q_i is the quantity produced by firm i, θ_i is the constant marginal cost of firm i and k is the fixed cost.[6] Marginal costs θ_i are firms' private information, but their distribution is common knowledge. We assume that the fixed cost k has to be spent before θ_1 and θ_2 are revealed to firms. The profits of the two firms can be written as:

$$\begin{aligned} \Pi_1 &= P(Q)q_1 - \theta_1 q_1 - k - \tau, \\ \Pi_2 &= P(Q)q_2 - \theta_2 q_2 - k, \end{aligned}$$

$Q = q_1 + q_2$ is the total duopoly quantity with τ being the regulatory instrument. This latter is a tax on profits when positive and a transfer when negative. We denote by λ the opportunity cost of public funds, due for example to the existence of distortionary taxation. Each euro that is transferred to the regulated firm costs $1+\lambda$ euros to society. In developed economies the cost of public funds is estimated around 0.3 (Snow and Warren, 1996). In developing countries, low income levels and inefficient tax system lead to higher

[4]It can be argued that it is much more common to regulate prices rather than quantities. Indeed, quantity competition allows us to concentrate on the direct impact of competition in concentrated markets, without incurring any Bertrand-type paradoxes. However, a model of price competition with close substitute goods would deliver the same qualitative predictions, especially relating to the welfare impact of liberalization.

[5]One key simplification in this model is that vertical issues (control of bottleneck facilities by the incumbent) are neglected. This can reflect the case in which the entrant can bypass the infrastructure of the incumbent. Alternatively, we can think of industries in which there is vertical unbundling (or at least formal separation) and access is priced at marginal cost.

[6]In this case, the competitor's fixed cost could include both an entry cost and the fixed investment by the competitor. The two together represent the additional cost borne by society for having two different producers, instead of the regulated firm producing the whole quantity. In our case, the fixed cost of the incumbent is exactly the same as that of the competitor. Having two different fixed costs would not qualitatively alter the results.

values (probably close to 1 on average and sensibly higher in heavily indebted countries). The profits of Firm 2 cannot be taxed away.[7] The social welfare function is then:

$$W = S(Q) - P(Q)Q + (1+\lambda)\tau + \Pi_1 + \Pi_2 \tag{1}$$

where $S(Q)$ is gross consumer surplus. The profits of both firms enter the social welfare function in equation (1). This would be the case were we to consider two national firms. Alternatively, we could think of a foreign firm whose participation produces some welfare gains for the host country (for instance because it creates employment). This specification has the advantage of allowing our results to be compared easily to those in the existing literature on liberalization. It is not however crucial for the nature of the results. Removing Firm 2's profits from the social welfare function yields the same qualitative results. We start by considering the case in which both firms have already entered the market; the entry decision is considered in more detail in Section 4.

The regulator maximizes welfare. Were production costs to be common knowledge, her problem would be simply to maximize (1) under the participation constraint $\Pi_1 \geq 0$ and the reaction function of the competitor $q_2 = r_2(q_1)$, where $r_2(q_1) = \text{argmax}_{q_2} \Pi_2$. This is a fairly standard problem, and its solution is discussed in the Working Paper version (Biancini, 2009). We here restrict our attention to the more realistic asymmetric-information case, and provide the intuition, where relevant, for any differences between these and those in the complete-information framework. When the regulator does not know the marginal production costs, the contract has to satisfy an incentive compatibility constraint: the regulator has to abandon a rent to the regulated firm in order to extract the information about their marginal cost.[8] However, the regulator does observe the final market price and/or quantity. This yields some information about θ_2 (and thus, when there is correlation, about θ_1). The regulator can use this information to instigate yardstick competition. As shown in Crémer and Mc Lean (1988), under certain conditions partial correlation can be sufficient for the principal to fully extract the surplus in an asymmetric-information problem. However, it seems reasonable to assume that in practice yardstick competition reduces the agency costs of asymmetric information, but does not eliminate them entirely. To convey this idea, we consider a specification inspired by Auriol and Laffont (1993). We assume that marginal costs of the two firms take the form $\theta_i = \beta + \varepsilon_i$, where β is the common part of marginal costs and ε_i is an idiosyncratic shock with zero mean. The common parameter β represents the average cost in the industry and captures the cost correlation. However, firms are also subject to idiosyncratic shocks which determine the relative efficiency of the different providers.

Assumption 1 *Let the marginal cost take the form $\theta_i = \beta + \varepsilon_i$. β is a discrete random variable which takes values $\underline{\beta}$ or $\overline{\beta}$ with $Prob(\beta = \underline{\beta}) = \nu$. ε is a continuous variable with distribution over the support $[\underline{\varepsilon}, \overline{\varepsilon}]$. Moreover, $\overline{\beta} + \underline{\varepsilon} = \underline{\beta} + \overline{\varepsilon} = z$.*

Marginal costs are thus either both distributed on the support $Z_1 = [\underline{\theta}, z]$ or on $Z_2 = [z, \overline{\theta}]$, with $\underline{\theta} < z < \overline{\theta}$ (either both costs are "low" or both are "high"). For simplic-

[7] This is a simplification reflecting the fact that national firms are more easy to tax than their foreign competitors. Alternatively, we can assume that both firms are subject to the general income tax, but that the regulated firm has a soft budget constraint.

[8] See Baron and Myerson (1982), and Laffont and Tirole (1993).

ity, we assume that the two intervals do not overlap.

We consider a direct-revelation mechanism in which Firm 1 reports its cost and the regulator offers a menu of contracts $[q_1(\theta_1), \tau(\theta_1, q_2)]$ for each possible type θ_1 (the revelation principle ensures that there is no loss of generality in restricting our attention to these kind of mechanisms). The contract is contingent on the realization of q_2. We assume that the regulator can commit to punish the manager of Firm 1 after q_2 has been observed, if the deduced value of θ_2 is inconsistent with the report of θ_1. This punishment notion does not contradict the fact that the participation constraint of the firm is always satisfied (Firm 1 never makes *accidental* losses, but managers could be prosecuted and/or replaced in the case of fraudulent behavior).

Under the stochastic structure described in Assumption 1, $\partial F(\theta_2|\theta_1)/\partial\theta_1 = 0$ almost everywhere (i.e. except if $\theta_1 = z$). A marginal variation in θ_1 does not change Firm 1's conditional expectation of Firm 2's characteristics (except in one case which occurs with probability zero). The advantage of this stochastic distribution is that it allows us to solve explicitly the first-order condition of the firm (the incentive-compatibility constraint) and to derive an expression for the expected rent (see below). Without the property $\partial F(\theta_2|\theta_1)/\partial\theta_1 = 0$, the problem would be intractable without further simplifying assumptions (Caillaud, 1990, for example, concentrates on the limiting cases of perfect correlation and independence). Our specification, inspired by Auriol and Laffont (1993), allows us to treat the case of partial correlation, which has hitherto been neglected in the literature. Moreover, this correlation in our model does not render the rent-extraction problem trivial (i.e. the distribution does not satisfy the Crémer and Mc Lean, 1988 conditions).

We denote the expected profit of Firm 1 by $\Pi(\theta_1) = E_{\theta_2|\theta_1}\Pi_1(\theta_1, \theta_2)$. Yardstick competition ensures that the information rent is paid only over the relevant interval of θ_1 and that types $\theta_1 = 1$ and $\theta_1 = z$ obtain zero rent.[9] The information rent can be computed applying by-now standard techniques (see for instance Laffont and Martimort, 2002). When $\beta = \overline{\beta}$ (i.e. $\theta_1 \in Z_2$), we have:

$$\Pi^D(\theta_1) = \int_{\theta_1}^{\overline{\theta}} E_{\theta_2|\theta_1}[q_1] d\theta_1$$

When $\beta = \underline{\beta}$ (i.e. $\theta_1 \in Z_1$):

$$\Pi^D(\theta_1) = \int_{\theta_1}^{z} E_{\theta_2|\theta_1}[q_1] d\theta_1$$

We thus obtain:

[9]This rent-reducing effect is different from the correlation effect analyzed in Caillaud (1990) and subsequently in the literature on strategic trade policy (see Brainard and Martimort, 1996, 1997 and Combes, Caillaud and Jullien, 1997). In these latter, the rent-seeking behavior of the regulated firm is modified by competition via the term $\partial F(\theta_2|\theta_1)/\partial\theta_1$. In our case $\partial F(\theta_2|\theta_1)/\partial\theta_1 = 0$ almost everywhere, but the yardstick effect reduces the rent of the regulated firm. Our specification avoids technical problems and allows us to characterize the effect of partial correlation on the optimal contract, relying on the realistic hypothesis that yardstick competition is used to reduce the agency cost of asymmetric information.

$$E_{\theta_1}\Pi_1^D(\theta_1) = \int_{\underline{\theta}}^{\overline{\theta}} \int_{\underline{\theta}}^{\overline{\theta}} \frac{F(\theta_1) - I_{Z_2}(\theta_1)F(z)}{f(\theta_1)} q_1(\theta_1) f(\theta_1, \theta_2) d\theta_1 d\theta_2 \tag{2}$$

where I_{Z_2} is the indicator function for θ_1 falling in region Z_2, which means:

$$I_{Z_2} = \begin{cases} 1, & \text{if } \theta_1 \in Z_2; \\ 0, & \text{otherwise.} \end{cases}$$

From Equation (2), the slope of the expected rent is lower than that in the benchmark monopoly case in which the rent is proportional to the full hazard rate:[10]

$$E_{\theta_1}\Pi_1^M(\theta_1) = \int_{\underline{\theta}}^{\overline{\theta}} \frac{F(\theta_1)}{f(\theta_1)} q_1(\theta_1) f(\theta_1) d\theta_1 \tag{3}$$

We make the following standard assumption:

Assumption 2 *The hazard rate $F(\theta_1)/f(\theta_1)$ is non-decreasing for all θ_1.*

The regulator chooses q_1 without observing θ_2, maximizing expected welfare. Substituting for the value of the rent (in order to satisfy the incentive-compatibility constraint), we have:

$$W = E_{\theta_1,\theta_2} \; S(Q) + \lambda P(Q)q_1 - (1+\lambda)(\theta_1 q_1 + k) - \theta_2 q_2 - \lambda \frac{F(\theta_1) - I_{Z_2}(\theta_1)F(z)}{f(\theta_1)} q_1 - k \tag{4}$$

Expected welfare (4) is maximized under the constraints:

$$q_2 = r_2(q_1) \tag{5}$$
$$q_1 \geq 0 \tag{6}$$
$$q_2 \geq 0 \tag{7}$$

Denoting by q_2^M the private monopoly quantity produced by Firm 2 when Firm 1 does not produce, and the price elasticity of demand by ε ($\varepsilon \equiv -\frac{\partial Q}{\partial P}\frac{P}{Q}$), the solution of the problem yields a rule for the expected price, which is characterized in the following Proposition.

Proposition 1 *Under Assumption 2, the pricing rule has the following properties:*

- *For larger values of θ_1 (Region M2), Firm 1 shuts down and the expected price is:*

$$E_{\theta_2|\theta_1} P(q_2^M)$$

[10] In the case of Firm 2 shutting down, the regulator cannot deduce the exact value of θ_2. Nevertheless, this does not necessarily affect the regulator's capability to reduce the rent of Firm 1. It is sufficient to assume that, whenever the regulated firm declares a marginal cost which is outside of the pertinent interval, Firm 2 produces a positive quantity, revealing the relevant subinterval of variable costs. For instance, we can easily show that this always holds under Assumptions 3 and 4. With the optimal menu of contracts, $q_2(q_1|\theta_1 \in Z_1, \hat{\theta}_1 \in Z_2) > 0$, $\forall \theta_1, \theta_2 \in Z_1$.

- *For smaller values of* θ_1 *(Region M1*$\cup$*D), the expected price is given by the modified Ramsey rule:*

$$E_{\theta_2|\theta_1}P(Q) = \theta_1^v + \frac{\lambda}{1+\lambda}\ E_{\theta_2|\theta_1}[\frac{1}{\varepsilon}(1+r_2'(q_1))\frac{q_1}{Q}P(Q)] - \frac{1}{1+\lambda}\ E_{\theta_2|\theta_1}[(P(Q)-\theta_2)r_2'(q_1)]$$

Proof See Appendix 1. ■

The quantities and the price vary depending on cost realizations. The relevant regions have the following characteristics:

- ***Smaller*** θ_1 ***(Region M1*** $\cup$ ***D):***

  In this region Firm 1 produces a positive quantity. The actual market structure depends on the value of θ_2. Firm 1 is a monopoly if $q_2 = 0$ (region M1) or a duopoly (region D). In Region D both firms are active, and the market is a true duopoly. Comparing this Ramsey-type tariff with the regulated-monopoly benchmark, we can separate three distinct effects. The first term in the price equation is the virtual cost $\theta_1 + \frac{\lambda}{1+\lambda}\frac{F(\theta_1)-I_{Z_2}(\theta_1)F(z)}{f(\theta_1)}$. This is smaller than that under monopoly $\theta_1 + \frac{\lambda}{1+\lambda}\frac{F(\theta_1)}{f(\theta_1)}$. The second term corresponds to the usual Ramsey term, multiplied by the elasticity of the total quantity to the quantity produced by Firm 1 (i.e. $[1 + r_2'(q_1)]\frac{q_1}{Q} = \frac{\partial Q}{\partial q_1}\frac{q_1}{Q} < 1$). The Ramsey term is thus smaller than that with a traditional regulated monopoly. The third term is also positive (i.e. $P(Q) \geq \theta_2$ in region D): this *increases* the price relative to a regulated monopoly. This last term captures the trade off between producing at lower cost (i.e. giving a greater market share to an oligopolistic firm) and reducing market price.

- ***Larger*** θ_1 ***(Region M2):***

  In region $M2$, Firm 1 produces a quantity of zero. In this case, Firm 2 produces its monopoly quantity and the price is $P(q_2^M)$. As θ_2 is not observable, the shut-down rule for Firm 1 now only depends on θ_1. There is thus a monopoly with Firm 2 for each level of θ_2 (Region M2). This parameter region includes points at which there would be shut-down under monopoly (and thus no production in the absence of Firm 2). In this case, a competitor with market power is valuable relative to the alternative of not providing the service at all.

2.1 Linear demand

We now consider a linear specification of demand, which allows us to compute price and quantities explicitly, and to compare them to the regulated-monopoly benchmark.

Assumption 3 *The (inverse) demand function is* $P(Q) = 1 - Q$.

We specify the stochastic structure of Assumption 1 as follows:

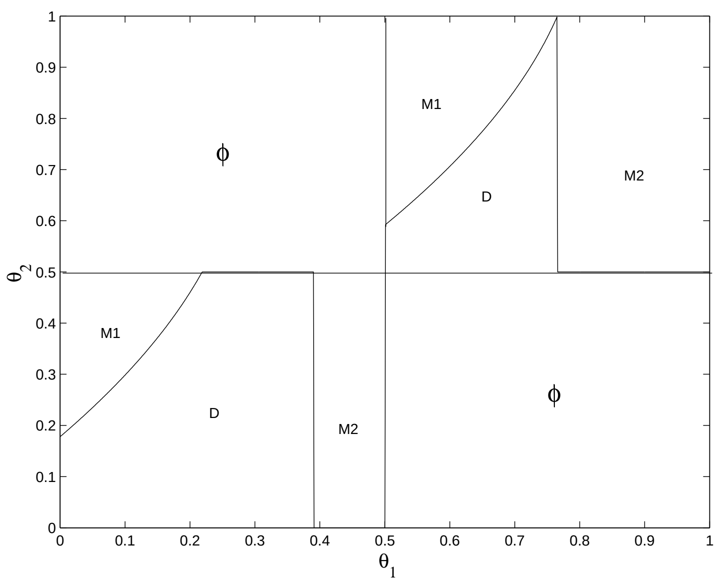
Assumption 4 *Let Assumption 1 hold and:*

$$\beta \in \{\tfrac{1}{4}, \tfrac{3}{4}\} \ , \quad Prob\{\beta = \tfrac{1}{4}\} = \tfrac{1}{2} \ , \quad \varepsilon \sim U[-\tfrac{1}{4}, \tfrac{1}{4}]$$

In this case, θ_i is uniformly distributed either over $Z_1 = [0, \frac{1}{2}]$ (with probability $\frac{1}{2}$) or over $Z_2 = [\frac{1}{2}, 1]$. Moreover, $z = \frac{1}{2}$. We thus have $E(\varepsilon_i) = 0$, $E(\theta_i) = E(\beta) = \frac{1}{2}$.

Under Assumptions 3 and 4, the regions implicitly characterized in Proposition 3 can be explicitly expressed in terms of the efficiency parameters θ_1 and θ_2. These are illustrated in Figure 1.[11]

Figure 1: Market structure with asymmetric information.



From Assumption 4, the two marginal costs are found in either the North-East or the South-West regions. Region M1 corresponds to the case in which the relative inefficiency of the entrant is high ($\theta_1 \ll \theta_2$) and no entry occurs. In Region D, both firms produce.

We now compare the duopoly quantities and price with those obtained under regulated monopoly.

Proposition 2 *Let $\theta_1, \theta_2 \in D$. Under Assumption 3, there exists a threshold $\phi(\lambda)$ such that:*

- *If $\lambda \leq \frac{1}{2}$, the expected price under incomplete regulation $E_{\theta_2|\theta_1} \ P(Q^D)$ is smaller than the regulated monopoly price $P(q_1^M)$ if and only if:*

$$E\theta_2 - \theta_1 \quad \geq \quad \phi(\lambda) \tag{8}$$

[11]This Figure is plotted for $\lambda = 0.3$, but the same qualitative shapes hold for all $\lambda > 0$.

- *If $\lambda > \frac{1}{2}$, the expected price under incomplete regulation $E_{\theta_2|\theta_1}\ P(Q^D)$ is always smaller than the regulated monopoly price $P(q_1^M)$.*

Proof See Appendix 2. ■

The threshold $\phi(\lambda)$ is derived in Appendix 2. When λ is not too large ($\lambda \leq \frac{1}{2}$),[12] there is a trade off between productive and allocative efficiency. Lower prices do not pertain when the relative efficiency of the entrant is larger (i.e. $E\theta_2 \ll \theta_1$), but rather when Firm 2 is expected to be not particularly efficient. In this case, the regulator increases the quantity produced by Firm 1 in order to reduce the scale of entry of the unregulated firm. This increases total quantity and reduces price. On the contrary, a fall in the average cost of production is not systematically transmitted to the price. When Firm 2 is relatively efficient, the price tends to be higher than that under monopoly, as the lower quantity produced by the regulated firm is not fully compensated by Firm 2's production.

3. Welfare analysis

In this Section, we compare expected welfare under regulated monopoly and incomplete regulation. First, note that, when $\lambda \to 0$, transfers are not costly and entry can be discouraged by expanding the regulated quantity when it is beneficial to do so (i.e. when the competitor is expected to be less efficient than the incumbent). Intuitively, expected welfare under duopoly (net of fixed costs) would then be greater than that under monopoly. On the contrary, as $\lambda \to \infty$, only the profit of the regulated firm matters. Since monopoly profit is always greater than Stackelberg profit, the welfare gains associated with competition approach $-\infty$ as $\lambda \to \infty$. For intermediate values of λ, the business-stealing effect of competition reduces the size of the tax (or increases the size of transfers), with a negative impact on welfare. This effect is mitigated by the fact that the presence of a competitor allows the information rent of the incumbent to be reduced. Yardstick competition, by increasing the productive efficiency of the regulated firm, allows quantity to be increased at a lower cost. Observing the market behavior of an unregulated firm provides precious information to the regulator, since this behavior is not distorted by regulation.[13] To provide a more precise characterization of what happens for intermediate values of λ, we again use the linear specification of Assumptions 3 and 4. This allows us to compute explicitly the welfare gains under symmetric and asymmetric competition respectively.

We denote by q_1^M the regulated monopoly quantity, q_i^D the duopoly quantity produced by Firm i, $i \in \{1, 2\}$ and by Q^D the total quantity. Under Assumptions 3 and 4, expected welfare under monopoly and duopoly is respectively:

[12] This threshold does not depend on the choice of $P(Q) = 1 - Q$, and holds for all linear demand specifications $p = a - bQ$ and $\theta_i \in [0, a]$.

[13] Naturally, this also depends on having ruled out the possibility of collusion between the incumbent and the entrant. Aubert and Pouyet (2006) show that in an incomplete-regulation framework, collusion (with transfers) may be preferred to a collusion-proof contract, because it allows the regulator and the incumbent to "team up" and tax or subsidize the entrant. The possibility of extracting a collusive transfer from the entrant could reduce the negative impact of business stealing. On the other hand, if firms collude, the effectiveness of yardstick competition might be reduced (see also Pouyet, 2002). Qualitatively, the main insights of our paper would continue to hold.

$$
\begin{aligned}
W^M &= E_{\theta_1,\theta_2}[q_1^M - \frac{(q_1^M)^2}{2} - \theta_1 q_1^M + \lambda(1 - q_1^M - \theta_1)q_1^M - (1+\lambda)k - \lambda\frac{F(\theta_1)}{f(\theta_1)}q_1^M] \\
W^D &= E_{\theta_1,\theta_2}[Q^D - \frac{(Q^D)^2}{2} - \theta_1 q_1^D - \theta_2 q_2^D + \lambda(1 - Q^D - \theta_1)q_1^D - (2+\lambda)k \\
&\quad - \frac{F(\theta_1) - I_{Z_2}(\theta_1)F(z)}{f(\theta_1)}q_1^D]
\end{aligned}
$$

Under asymmetric information, duopoly is preferred to monopoly if $W^D - W^M \geq 0$. This determines a threshold value of k, characterized by the following Proposition.

Proposition 3 *Under Assumptions 3 and 4 hold, we have two cases:*

1. *For $\lambda \leq 3.7$, there exists a threshold $\overline{k}$ such that partially-regulated duopoly dominates regulated monopoly for $k \leq \overline{k}$; the threshold $\overline{k}$ is hump-shaped in λ.*

2. *For $\lambda > 3.7$ regulated monopoly always dominates partially-regulated duopoly.*

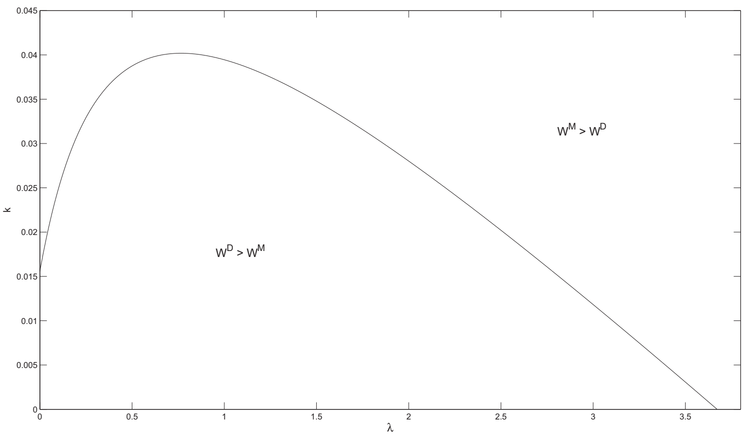
Proof See Appendix 2. ■

Regulated monopoly always (i.e. independently of the economies of scale) dominates incomplete regulation for large values of λ only (values larger than 3 are usually considered not to be empirically relevant). For lower values, the threshold $\overline{k}$ is hump-shaped. For smaller values of λ, an increase in λ makes competition more valuable, as it helps to reduce the expected rent of the regulated firm and the distortion in production associated with asymmetric information. Welfare thus increases. However, as λ becomes larger, the profit of the regulated firm becomes more valuable and the business-stealing effect prevails, making entry less desirable.[14] This negative business-stealing effect is also found under complete information, while the positive rent-reduction effect depends on asymmetric information. Biancini (2009) shows that under complete information the relevant threshold would generally be lower (i.e. asymmetric information favors duopoly) and falls with λ. Under asymmetric information, duopoly is more often preferred because it has the additional value of reducing the expected rent of the regulated firm and the associated distortions. However, as the cost of public funds becomes larger, the business-stealing effect prevails and the benefits of competition are reduced.

The results here are thus in line with the common view that competition can be welfare increasing if economies of scale are not too large. However, we have shown that the cost of public funds is key for determining the relevant threshold. For the same economies of scales, countries with different costs of public funds optimally choose different industrial

[14]This welfare result does not depend critically on the duopoly structure. Aubert and Pouyet (2004) show that, when a regulated incumbent is exposed to a competitive fringe, welfare can be higher when the fringe colludes (behaving as a duopolistic competitor) rather than behaving competitively. A similar effect is at work here: introducing competition does not necessarily increase welfare when λ is higher. However, with more competitors, the sampling effect (i.e. the probability of finding more efficient producers) would also be larger (Aubert and Pouyet, 2004 concentrate only on the case of identical costs).

Figure 2: The $\overline{k}$ threshold



policies. For instance, in our specification, if $k \simeq 0.035$, a country with low costs of public funds will prefer to keep a statutory monopoly, for intermediate values a duopoly is preferred, and finally for large values of λ the monopoly structure once again becomes optimal.

This $\overline{k}$ threshold is plotted in Figure 2.

4. Excess entry

Up to now, we have supposed that both firms have invested k and entered the market. The regulatory contract satisfies the ex-post participation constraint of Firm 1, so that Firm 1 is always in the market. We now consider the entry decision of Firm 2. To participate, Firm 2 has to spend k before finding out the level of variable costs. We denote by $\overline{k}_2$ the threshold of k below which Firm 2 finds it *privately* profitable to enter the market. This is given by the values of the fixed cost below which expected profits are non-negative. The results are summarized in the following Proposition.

Proposition 4 *Under Assumptions 3 and 4, the level of fixed costs under which Firm 2 finds it privately profitable to enter the market is higher than the level below which entry is socially valuable. Excess entry occurs.*

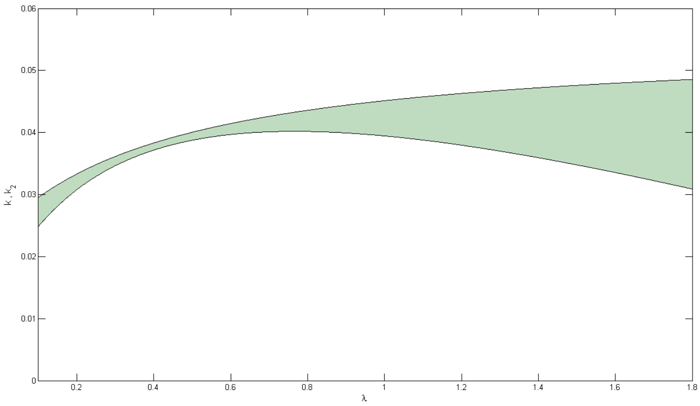
Proof See Appendix 2. ■

These results are depicted in Figure 3. The shaded regions correspond to the parameter values for which excess entry occurs.

Excess entry depends on the fact that Firm 2 does not internalize the impact of its entry on Firm 1's profit (and on taxpayers). There are thus cases in which the regulator is willing to control entry.[15]

[15] Biancini (2009) shows this is also the case under complete information.

Figure 3: Excess Entry



5. Incomplete vs full regulation

We have to date ruled out the possibility that all firms in the market are subject to the same regulatory scheme. This may be realistic in some liberalized markets (as noted in Section 1). However, we could imagine that, at least from a theoretical point of view, full market regulation is always preferable to incomplete regulation, unless extending the scope of regulation is not feasible or very costly. On the contrary, the welfare gains from liberalization under incomplete regulation are quite robust and incomplete regulation may be even preferred to full regulation. To show this, we now compare welfare under incomplete regulation with welfare in the case of full duopoly regulation. For the full-regulation benchmark, we use the model of Auriol and Laffont (1993), where the quantities of both firms are regulated and subject to a lump-sum tax/transfer. Then, using our notation, the profit of Firm i can be written as:

$$\Pi_i = P(Q)q_i - \theta_i q_i - k - \tau_i, \;\; i \in \{1, 2\}$$

and expected welfare is:

$$W^R = E_{\theta_1,\theta_2}\; S(Q) - P(Q)Q + \Pi_1 + \Pi_2 + (1+\lambda)(\tau_1 + \tau_2) \tag{9}$$

The regulator's problem is to maximize (9) with respect to q_1, q_2, τ_1, and τ_2. Since variable costs are linear, at the optimum only the most efficient firm will produce and the pricing rule is that of traditional regulated-monopoly Ramsey pricing. Due to yardstick competition, virtual cost has the same shape as in our Proposition 3 (for further details, see Auriol and Laffont, 1993). The pricing rule then satisfies:

$$P(Q) = \min\{\theta_1^v, \theta_2^v\} + \frac{\lambda}{1+\lambda}\frac{P(Q)}{\varepsilon}$$

Under complete information, full regulation always dominates incomplete regulation. The intuition here is natural. The regulator commits to cover the fixed costs of both firms, but at the same time she can extract their full operating profit. As a result, full regulation can at least replicate the results obtained by an unregulated competitor. Under asymmetric information, the situation is more complex. Regulated firms are able to obtain some information rent and the relevant production cost for the regulator is the virtual cost $\theta_i^v \geq \theta_i$. Due to this distortion, the regulator cannot extract the full operating profit. Under full regulation, she induces production at the distorted virtual cost under a contract which covers both fixed costs at their social value $(1 + \lambda)k$. On the contrary, under incomplete regulation the competitor is fully accountable for both its profits and losses (and does not receive any subsidy). With a high value of λ, the agency cost of regulation may outweigh its benefits, and incomplete regulation dominates full regulation. This result is stated formally in the following proposition for the case of linear demand.

Proposition 5 *Let Assumptions 3 and 4 hold. Then, in the case of asymmetric information, partial regulation dominates full duopoly regulation when* λ *and* k *are sufficiently large.*

Proof See Appendix 2. ■

Figure 4: Incomplete vs full regulation

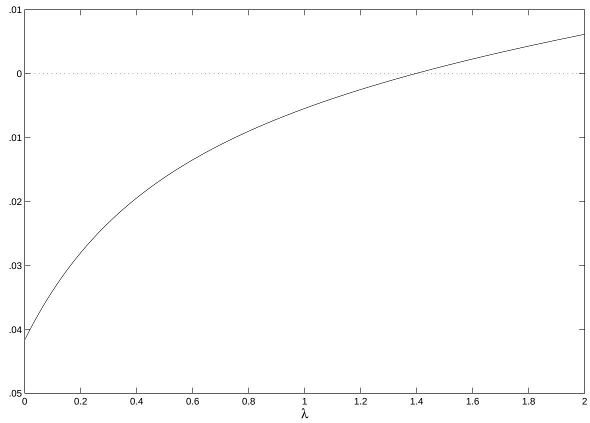


Figure 4 depicts the welfare difference between incomplete and full regulation when $k = \overline{k}_2$, which is the maximum value of fixed costs that a private firm is willing to pay (i.e. the maximum value for which a second firm exists). When $k = \overline{k}$ the "savings" related to not committing to cover the fixed costs of Firm 2 are maximal. However, the same result could be obtained for any value of k introducing an ex-ante fixed fee for the unregulated competitor (a licence fee). The model shows that incomplete regulation can be the optimal choice for governments which are limited by severe cash constraints (e.g. less-developed countries), combining the benefits of keeping some regulated provision with the advantages of private participation.

6. Conclusion

The paper has discussed the impact of opening up a regulated monopoly to unregulated competition. It presents a model from liberalization with incomplete regulation: the regulator contracts with the incumbent, but can only indirectly influence the behavior of the competitor. We have revealed a trade off between encouraging production by a relatively efficient competitor (increasing productive efficiency) and the market power of this competitor (which leads to allocative inefficiency). Entry can be associated with higher prices when the entrant is more efficient than the incumbent. Greater efficiency can then be associated with higher prices and profits, which is consistent with empirical evidence. The desirability of introducing this kind of competition thus depends on the weight the regulator puts on consumer surplus. The cost of public funds, which determines the weight put on the incumbent's operating profits, is shown to play an important role in this welfare analysis. In particular, the welfare gains from liberalization not only depend on the degree of increasing returns to scale (as measured by the fixed costs), but also on the cost of public funds. In the presence of yardstick competition, unregulated competition reduces the burden of the information rent. However, the fiscal aspects of competition, related to taxation by regulation, should also be taken into account by policy makers. When other forms of taxation (e.g. income taxation) are costly, business stealing can reduce the gains from deregulation. The relationship between the cost of public funds and the welfare gains from liberalization is non-monotone. Countries can thus differ in their optimal industry structures, for the same level of increasing returns to scale. The importance of the information asymmetry and the tightness of the government's cash constraint are empirical issues. Information on both of these can help governments to choose optimal industry regulation. In the last section of the paper, we show that the welfare gains from liberalization under incomplete regulation are robust. For a substantial cost of public funds, incomplete regulation may even dominate the full regulation of the duopoly. Developing countries are typically characterized by tighter budget constraints. Partial liberalization could then be a solution to their peculiar problems, combining some form of publicly-managed provision with the advantage of shifting part of the fixed investment and responsibility for market results onto the private sector. One possible drawback of partial deregulation is that excess entry occurs. Our analysis here confirms the importance of entry regulation in increasing returns to scale industries.

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Appendix 1

Proof of Proposition 1:

The regulator maximizes expected welfare (4), taking into account (3) and (5)-(7). The solution is obtained from the first-order condition with respect to q_1, when this yields a positive solution (Region $M1 \bigcup D$).

$$E_{\theta_2|\theta_1} \;\; [P(Q) - \theta_1^v + \frac{\lambda}{1+\lambda}(1 + r'(q_1))P'(Q)q_1 + \frac{1}{1+\lambda}(P(Q) - \theta_2)r_2'(q_1)] = 0 \qquad (10)$$

Rearranging (10), we obtain the modified Ramsey formula which prevails in Region $M1 \bigcup D$. In addition, the second-order condition is:

$$E_{\theta_2|\theta_1} \;\; [(P(Q)-\theta_2)r_2''(q_1)+\lambda P''(Q)(1+r_2'(q_1))^2 q_1+P'(Q)(1+r_2'(q_1)(1+2\lambda+r_2'(q_1))+\lambda q_1 r_2''(q_1))] \leq 0$$

Using the first- and second-order conditions, it easy to see that the optimal q_1 must fall in θ_1^v. The non-negativity constraint $q_1 \geq 0$ is then not binding if and only if θ_1 is not too large; otherwise, $q_1 = 0$ (Region $M2$) and the expected price is given by the expected monopoly price of the competitor, namely $E_{\theta_2|\theta_1} \; P(q_2^M)$.

Linear Demand:

We now consider the case of linear demand and a distribution of θ_i as in Assumption 4. In this case:

$$q_2 = \max\Big[0, \frac{1}{2}(1 - q_1 - \theta_2)\Big]$$

Note that $q_2 = 0$ whenever $\theta_2 \leq 1 - q_1$. The optimal q_1 is obtained by considering separately the two cases θ_1 in $[0, \frac{1}{2}]$ and θ_1 in $[\frac{1}{2}, 1]$. For both cases, we consider the possibility that $1 - q_1 \leq \frac{1}{2}$ or $1 - q_1 \geq \frac{1}{2}$. We thus have four possible cases:

Case 1: Consider first θ_1 in $[0, \frac{1}{2}]$ and $[1 - q_1 \leq \frac{1}{2}]$ (i.e. $q_1 \geq \frac{1}{2}$). The objective is:

$$\max_{q_1 \in [\frac{1}{2},1]} \quad \int_{1-q_1}^{\frac{1}{2}} \Big[q_1 - \frac{q_1^2}{2} + \lambda(1-q_1)q_1 - (1+\lambda)\theta_1 q_1 - \lambda\theta_1 q_1\Big] \, 2 \, d\theta_2 + \int_0^{1-q_1} \Big[q_1 + q_2 - \frac{(q_1+q_2)^2}{2} + \lambda(1-q_1-q_2)q_1 - (1+\lambda)\theta_1 q_1 - \theta_2 q_2 - \lambda\theta_1 q_1\Big] \, 2 \, d\theta_2$$

The first-order condition with respect to q_1 yields:

$$q_1 = \frac{1 + 2\sqrt{1 + 3\lambda(1+\lambda) - 3\theta_1(1+2\lambda)^2}}{3(1+2\lambda)}$$

Case 2: Consider now θ_1 in $[0, \frac{1}{2}]$, with q_1 such that $[1 - q_1 > \frac{1}{2}]$. The objective in this case is:

$$\max_{q_1 \in [0,\frac{1}{2}]} \int_0^{\frac{1}{2}} \left[q_1 + q_2 - \frac{(q_1+q_2)^2}{2} + \lambda(1-q_1-q_2)q_1 - (1+\lambda)\theta_1 q_1 - \theta_2 q_2 - \lambda\theta_1 q_1 \right] 2\, d\theta_2$$

The first-order condition produces:

$$q_1 = \frac{7 + 10\lambda - 16\theta_1(1+2\lambda)}{4\,(1+4\lambda)}$$

Case 3: With θ_1 in $[\frac{1}{2}, 1]$ and q_1 such that $[1 - q_1 \leq \frac{1}{2}]$, the objective is:

$$\max_{q_1 \in [\frac{1}{2},1]} \int_{\frac{1}{2}}^{1} \left[q_1 - \frac{q_1^2}{2} + \lambda(1-q_1)q_1 - (1+\lambda)\theta_1 q_1 - \lambda\theta_1 q_1 \right] 2\, d\theta_2$$

The first-order condition yields:

$$q_1 = \frac{2 + 3\lambda - 2\theta_1(1+2\lambda)}{2\,(1+2\,\lambda)}$$

Case 4: Consider θ_1 in $[\frac{1}{2}, 1]$ and q_1 such that $[1 - q_1 > \frac{1}{2}]$. The objective becomes:

$$\begin{aligned}\max_{q_1 \in [0,\frac{1}{2}]} \quad & \int_{1-q_1}^{1} \left[q_1 - \frac{q_1^2}{2} + \lambda(1-q_1)q_1 - (1+\lambda)\theta_1 q_1 - \lambda\theta_1 q_1 \right] 2\, d\theta_2 + \\ & + \int_{\frac{1}{2}}^{1-q_1} \left[q_1 + q_2 - \frac{(q_1+q_2)^2}{2} + \lambda(1-q_1-q_2)q_1 - (1+\lambda)\theta_1 q_1 - \theta_2 q_2 - \lambda\theta_1 q_1 \right] 2\, d\theta_2\end{aligned}$$

The first-order condition gives:

$$q_1 = \frac{(-1 - 4\lambda + 2\sqrt{10 + 38\lambda + 37\lambda^2 - 12\theta_1(1+2\lambda)^2}}{6(1+2\lambda)}$$

Checking the second-order condition and controlling for the fact that any quantity has to belong to the interval $[0, 1]$, we have a solution of the form:

$$q_1^{D,AI} = \begin{cases} \frac{1+2\sqrt{1+3\lambda(1+\lambda)-3\theta_1(1+2\lambda)^2}}{3(1+2\lambda)}, & 0 \leq \theta_1 \leq \frac{5+2\lambda}{16(1+2\lambda)}; \\ \frac{7+10\lambda-16\theta_1(1+2\lambda)}{4(1+4\lambda)}, & \frac{5+2\lambda}{16(1+2\lambda)} \leq \theta_1 \leq \frac{7+10\lambda}{16(1+2\lambda)}; \\ 0, & \frac{7+10\lambda}{16(1+2\lambda)} \leq \theta_1 \leq \frac{1}{2} \text{ or } \frac{13+22\lambda}{16(1+2\lambda)} \leq \theta_1 \leq 1; \\ \frac{-1-4\lambda+2\sqrt{10+38\lambda+37\lambda^2-12\theta_1(1+2\lambda)^2}}{6(1+2\lambda)}, & \frac{1}{2} < \theta_1 \leq \frac{13+22\lambda}{16(1+2\lambda)}. \end{cases} \tag{11}$$

$$q_2^{D,AI} = \begin{cases} \max\left[0, \frac{2+6\lambda-3\theta_2(1+2\lambda)-2\sqrt{1+3\lambda(1+\lambda)-3\theta_1(1+2\lambda)^2}}{6(1+2\lambda)}\right], & 0 \leq \theta_1 \leq \frac{5+2\lambda}{16(1+2\lambda)}; \\ \frac{-3+6\lambda+16\theta_1(1+2\lambda)-4\theta_2(1+4\lambda)}{8(1+4\lambda)}, & \frac{5+2\lambda}{16(1+2\lambda)} \leq \theta_1 \leq \frac{7+10\lambda}{16(1+2\lambda)}; \\ \frac{1-\theta_2}{2}, & \frac{7+10\lambda}{16(1+2\lambda)} \leq \theta_1 \leq \frac{1}{2} \text{ or } \frac{13+22\lambda}{16(1+2\lambda)} \leq \theta_1 \leq 1; \\ \max\left[0, \frac{(7+16\lambda-6\theta_2(1+2\lambda)-2\sqrt{10+38\lambda+37\lambda^2-12\theta_1(1+2\lambda)^2}}{12(1+2\lambda)}\right], & \frac{1}{2} < \theta_1 \leq \frac{13+22\lambda}{16(1+2\lambda)}. \end{cases} \tag{12}$$

Appendix 2

All the results of Propositions 2-5 require us to compute expectations with respect to the cost realizations. Using quantities (11) and (12), we can derive the explicit expressions for the different regions. We have:

$$\begin{aligned}
M1 &= \left\{(\theta_1,\theta_2)\in[0,\frac{1}{2}] \text{ s.t. } \theta_1 \leq \frac{4\theta_2(1+3\lambda)-4\lambda-3\theta_2^2(1+2\lambda)}{1+2\lambda}\right\} \\
&\bigcup \left\{(\theta_1,\theta_2)\in[\frac{1}{2},1] \text{ s.t. } \theta_1 \leq \frac{4\theta_2(7+16\lambda)-12\theta_2^2(1+2\lambda)-3(1+6\lambda)}{16(1+2\lambda)}\right\} \\
D &= \left\{(\theta_1,\theta_2)\in[0,\frac{1}{2}] \text{ s.t. } \frac{4\theta_2(1+3\lambda)-4\lambda-3\theta_2^2(1+2\lambda)}{1+2\lambda} \leq \theta_1 \leq \frac{7+6\lambda}{16(1+2\lambda)}\right\} \\
&\bigcup \left\{(\theta_1,\theta_2)\in[\frac{1}{2},1] \text{ s.t. } \frac{4\theta_2(7+16\lambda)-12\theta_2^2(1+2\lambda)-3(1+6\lambda)}{16(1+2\lambda)} \leq \theta_1 \leq \frac{13+22\lambda}{16(1+2\lambda)}\right\} \\
M2 &= \left\{(\theta_1,\theta_2)\in[0,\frac{1}{2}] \text{ s.t. } \theta_1 \geq \frac{7+6\lambda}{16(1+2\lambda)}\right\} \bigcup \left\{(\theta_1,\theta_2)\in[\frac{1}{2},1] \text{ s.t. } \theta_1 \geq \frac{13+22\lambda}{16(1+2\lambda)}\right\}
\end{aligned}$$

Proof of Proposition 2:

Using Equations (11) and (12) under Assumption 3, we can easily show that $E_{\theta_2|\theta_1}P(Q^D) \leq P(q_1^M)$ if and only if:

$$E\theta_2 - \theta_1 \geq \phi(\lambda) \tag{13}$$

where:

$$\phi(\lambda) = \begin{cases} -\frac{1+4\lambda(3\lambda-2)}{4(1+2\lambda)^2}, & \text{if } E\theta_2 = \frac{1}{4} \text{ and } \lambda \leq \frac{1}{6}; \\ \frac{\lambda(6\lambda-1)}{4(1+2\lambda)}, & \text{if } E\theta_2 = \frac{1}{4} \text{ and } \lambda > \frac{1}{6}; \\ -\frac{1+4\lambda+4(1+\lambda)\sqrt{\lambda(2+5\lambda)}}{4(1+2\lambda)^2}, & \text{if } E\theta_2 = \frac{3}{4}. \end{cases}$$

For $\theta_1, \theta_2 \in D$, this is always satisfied for $\lambda \geq 1/2$.

Proofs of Propositions 3-5:

The thresholds $\overline{k}$ and $\overline{k}_2$ and the threshold value of Proposition 5 are obtained as analytical functions of λ integrating above the intervals of the realizations of θ_1 and θ_2. The analysis of these functions yields all of the results (further details are available on request).