Contributions

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The Signaling Role of Subsidies

Abstract: This paper investigates the effect of monopoly subsidies on entry deterrence. We consider a potential entrant who observes two signals: the subsidy set by the regulator and the output level produced by the incumbent firm. We show that not only a separating equilibrium can be supported, where information about the incumbent's costs is conveyed to the entrant, but also a pooling equilibrium, where the actions of regulator and incumbent conceal the monopolist's type, thus deterring entry. We demonstrate that the regulator strategically designs subsidies to facilitate, or hinder, entry deterrence, depending on which outcome yields the largest social welfare. Furthermore, we compare equilibrium welfare relative to two benchmarks: complete-information environments and standard entry-deterrence games where the regulator is absent.

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1 Introduction

Several monopolized industries often benefit from subsidies allowing them to increase their output levels. For instance, Monsanto sells more than 70% of genetically modified seeds in the U.S. and has consistently received subsidies from the USDA.[1] In the context of U.S. commercial airlines, Goldsbee and

1 In particular, the USDA Federal Crop Insurance Corporation offers significant insurance discounts (about $2 per acre, or $2,000 for a typical 1,000-acre farm) to farmers who plant 75–80% of their crops using Monsanto's genetically modified seeds. Importantly, these insurance discounts are *not* offered to farmers using genetically modified seeds from other firms. Similarly, the Korean steel company Posco, which until 1992 had monopoly status for many of

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Syverson (2008) empirically show that some airlines, initially operating as monopolies in the route between two cities, decide to significantly reduce prices in order to prevent entry. Despite their entry-deterring behavior, commercial airlines have recurrently benefited from output-related subsidies.[2, 3]

Despite their widespread use, the regulation literature has overlooked the informative content that subsidies provide to potential entrants. In this paper, we demonstrate that subsidy policy can help the incumbent firm conceal information from potential entrants, thus hindering entry and competition under certain conditions. In addition, we show that subsidies can be welfare improving, despite their negative effect on entry. Our results, hence, suggest that the regulator strategically designs subsidies to reveal or conceal information, depending on which outcome yields the largest social welfare.

We examine an entry-deterrence game in which a regulator provides a per-unit subsidy in each period. In particular, we consider settings where the incumbent firm has been recently privatized after being publicly owned and managed for several years, allowing the regulator to accumulate information about the incumbent's costs.[4] In this context, the potential entrant, being uninformed about the incumbent's costs, observes two signals to assess market prospects: the

its products in the domestic market, also received output-related subsidies. For instance, the Korean government provided Posco with discounted user rates for many government services, such as discounted railroad rate of 40%, port rate of 50%, water-supply rate of 30%, and gas rate of 20%. For more details on the subsidies to Posco, see Amsden (1989) and Park (2003).

2 As part of the Essential Air Service program, the U.S. Department of Transportation provides output-related subsidies to airlines serving 152 rural communities across the country. These companies frequently maintain a monopolistic position on this type of routes and receive subsidies from this program which, in certain flights, can reach an average of $74 per passenger; see Bailey (2006).

3 Finally, the industry of electricity production is often regarded as a regional monopoly in many states across the U.S. and firms in this sector have also received generous federal and state subsidies to increase production. According to Slocum (2007), for instance, 92% of U.S. households have no ability to choose an alternative electricity supplier, since the wholesale market of power generation is essentially monopolized. Federal subsidies directly related to electricity production were estimated at $6.7 billion in 2007, or about 41% of total energy subsidies; see EIA (2008).

4 Several public companies were privatized in the United Kingdom, such as British Steel (in 1988) and British Energy (in 1996). Other examples include Petro-Canada (1991) and Nova Scotia Power (1992) in Canada. In addition, many planned economies have also experienced major privatization processes, such as Russia with LUKOil (1995) and Novolipetsk Steel (1995). Many of these firms still receive generous subsidies, such as LUKOil, the largest oil producer in Russia, which benefited from a large share of the US$100 billion in subsidies directed to fossil-fuel producers in 2009, IEA (2010). For accounts of these privatization processes, see Kay and Thompson (1986) and Waterson (1988). Finally, China has recently started to privatize some public companies, as reported by the OECD (2009) and Gan, Guo, and Xu (2012).

incumbent's output level, as in standard entry-deterrence games, but also the subsidy set by the regulator. As a consequence, we study a new role of subsidies since, in addition to their standard goal to induce efficient output levels, they can be used as a tool to facilitate the transmission of information, thus promoting or deterring entry. The case of Dow Chemicals, a monopolist in the U.S. magnesium industry, provides evidence of entry-deterring practices facilitated by regulation. Regulators accumulated information about Dow's production during the Korean War, a period in which magnesium production plants were publicly owned and managed. In 1970, the EPA introduced the National Ambient Air Quality Standards (NAAQS), affecting the emission of two pollutants generated in the production of magnesium: carbon monoxide and particulate matter. The following year, however, the state of Texas, where most Dow magnesium plants were located, passed its own Clean Air Act, allowing Dow to ignore some of the emission requirements in the NAAQS. Such state law can, hence, be interpreted as an output subsidy to Dow. Interestingly, this implicit subsidy led Dow to substantially increase its magnesium production during the early 1970s, which successfully deterred the entry of potential competitors, such as Kaiser Aluminum and Norsk Hydro, and delayed the entry of Alcoa until 1976.[5]

The paper shows the existence of two types of equilibrium outcomes: a separating equilibrium, where information about the incumbent's costs is fully revealed to the entrant, and a pooling equilibrium (PE), where such information is concealed. In the separating equilibrium, the actions of both informed agents (regulator and incumbent) convey the incumbent's type to the entrant, i.e. they both choose the same type-dependent strategies as under complete information. Hence, the presence of an additional signal (originating from the regulator) induces players to behave as under complete-information contexts, entailing a similar welfare level; a non-distortionary result in the line of models in which the entrant observes signals stemming from two incumbent firms, such as Bagwell and Ramey (1991) and Schultz (1999).

This non-distortionary finding, however, does not imply that the regulator's presence in a setting of incomplete information is welfare neutral. Instead, the regulator's ability to induce optimal output levels during both periods produces a positive effect on welfare, ultimately yielding an unambiguously larger welfare than in signaling games where the regulator is absent.

In the PE, in contrast, both regulator and incumbent's actions conceal information from the entrant (they select type-independent strategies), thus deterring entry. In particular, the high-cost incumbent increases its output – in order to mimic the low-cost incumbent, i.e. it "overproduces" –while the regulator

5 For more details, see Lieberman (1987), Rosenbaum (1998), and Friedrich and Mordike (2006).

provides the subsidy corresponding to the low-cost incumbent, i.e. he "over-subsidizes." By setting such a subsidy, the regulator gives rise to negative and positive welfare effects: on the one hand, he induces the production of an inefficient output level but, on the other hand, entry is deterred, thus entailing savings in entry costs. As a consequence, the regulator is only willing to "over-subsidize" when the savings in entry costs offset the welfare loss that arises from overproduction. In this setting, regulator's and incumbent's preferences are aligned and, hence, the former supports the firm's entry-deterring practices. In contrast, their preferences about entry are misaligned if suboptimal subsidies generate large welfare losses. In this case, the regulator prefers to behave as under complete information, thus hindering the incumbent's ability to deter entry.

We furthermore show that the PE is more likely to emerge when firms' costs are symmetric, i.e. the difference between a high- and low-cost incumbent is small. Specifically, the welfare loss that arises from the incumbent's mimicking effort diminishes as costs become symmetric, thus expanding the set of parameters under which this equilibrium can be sustained. From a policy perspective, this result suggests that policies that support inefficient firms in their acquisition of more advanced technologies would actually facilitate the concealment of information from potential entrants, further promoting entry deterrence.

Our findings, hence, show that regulatory agencies can strategically facilitate or inhibit the entry-deterring practices of established firms, an element often ignored when designing or evaluating subsidy programs to monopolized industries. While these programs might entail entry-deterring consequences, our results demonstrate that their welfare effects might be positive.

1.1 Related literature

Our paper contributes to the literature on monopoly regulation where the social planner has accurate information about the incumbent's costs, extended by Baron and Myerson (1982) to contexts where the regulator does not observe the incumbent's costs, and further developed by Laffont and Tirole (1986) and Lewis and Sappington (1989).[6] Unlike these articles, however, we consider a setting where a regulated monopolist faces the threat of entry in the next period. In the complete-information game, we show that monopoly subsidies cannot be used to deter

6 In particular, Laffont and Tirole (1986) consider the effects of distortive taxation on optimal regulation, showing the existence of a trade-off between the information rent of the regulated firm and efficiency. Lewis and Sappington (1989) extend the Baron–Myerson model by having the regulator not only uninformed about a firm's marginal cost but also about its fixed costs, the latter being negatively correlated with the former.

entry, since the entry decision solely depends on the incumbent's efficiency level.[7] Under incomplete information, however, monopoly subsidies can be used to convey or conceal information, thus affecting entry in the industry.

Our paper also connects to entry-deterrence models where the regulator is absent; see Milgrom and Roberts (1982), Harrington (1986), and Ridley (2008). Unlike these studies, we analyze firms' actions within a standard regulatory framework and investigate the effects of regulation on entry deterrence and competition. Since the uninformed entrant observes two signals, our model relates to the signaling literature that considers industries in which the uninformed party observes several signals, originating from either one or multiple senders. Milgrom and Roberts (1986), for instance, analyze an informed firm who uses two signals, price and advertising, to convey the quality of its product to potential customers.[8] While we also study information transmission with two signals, in our model they stem from two different informed agents (the regulator and the incumbent), rather than from the same player. We demonstrate that, in contrast to their results, the presence of two informed agents can support the emergence of a PE in which information about the incumbent's costs is concealed from the entrant, thus deterring entry.

This paper is, hence, closer to entry-deterrence models in which the uninformed player observes signals originating from different senders; such as Harrington (1987) and Bagwell and Ramey (1991), who study the use of limit pricing by two incumbent firms with common private information about their production costs.[9, 10] Our analysis is specially connected to Schultz's (1999)

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7 In a setting where the regulator strategically selects trade and subsidy policy, Dixit and Kyle (1985) show that a perfectly informed regulator can affect the entry decision of foreign firms. Their paper, however, does not analyze the signaling role of subsidy policy.

8 Bagwell and Ramey (1990) and Albaek and Overgaard (1994) also examine entry deterrence in a model where the potential entrant can perfectly observe both the incumbent's pre-entry pricing strategy and its advertising expenditures.

9 Martin (1995) considers an industry where two incumbent firms might have different, rather than common, production costs, which each of them privately observes. He shows that each incumbent's incentives to signal its own production cost to its rival and to the potential entrant allow for the emergence of pooling strategy profiles under conditions that did not support this type of equilibrium when all firms share the same production cost.

10 These models also relate to the literature that examines industries in which two or more firms use two signals, price and expenditure on uninformative advertising, to convey their product quality to uninformed consumers; as in Hertzendorf and Overgaard (2001) and Fluet and Garella (2002), which extend Milgrom and Robert's (1986) model to two firms. Daughety and Reinganum (2007) further develop such information setting in two respects: first, allowing for each firm to privately observe the quality of its own product, rather than assuming that both firms can observe each other's qualities and, second, considering that consumers can have

study of entry deterrence in markets where two incumbent firms have opposing interests regarding entry. He finds that a PE can be supported whereby firms' signals conceal information about market demand from the entrant, thus deterring it from the industry. This PE emerges when the interests of both firms are similar. We likewise show that such equilibrium arises when the regulator's and incumbent's preferences are aligned. Our paper, furthermore, shows that such equilibrium, despite deterring entry, unambiguously entails a welfare improvement relative to complete information.[11] By contrast, if their preferences are misaligned, subsidy policy inhibits the incumbent's concealment of information, and entry occurs.[12]

The next section describes the model under complete information. Section 3 examines the signaling game, and Sections 4 and 5 analyze the separating equilibrium and PE, respectively, also providing welfare comparisons. Section 6 discusses our equilibrium results and policy implications.

2 Complete information

Let us examine an entry game where a monopolist incumbent initially operates and an entrant must decide whether or not to join the market. In addition, consider a regulator who sets a subsidy per unit of output in every stage of the game. This section analyzes the case where all players are informed about the incumbent's marginal cost, while Sections 3–5 examine the case in which the entrant is unable to observe such a cost. We study a two-stage game where, in

different preferences for the good that each firm offers. For other recent models analyzing firms' signal of their product quality, see Daughety and Reinganum (2008) and Levin, Peck, and Ye (2009).

11 Espinola-Arredondo and Munoz-Garcia (2013) examine a similar information setting, whereby a polluting firm faces the threat of entry. Their paper, however, focuses on how the incumbent's overproduction decision, in order to deter entry, generates more pollution, which gives rise to an additional form of inefficiency, absent under complete information, ultimately calling for a stricter environmental policy.

12 In the field of capital-structure decisions, Gertner, Gibbons, and Sharfstein (1988) analyze an enlarged entry-deterrence model where an informed firm sends a signal about its profitability to two uninformed audiences: the capital and product market. In particular, Gertner, Gibbons, and Sharfstein (1988) show that the emergence of the separating equilibrium or PE in the capital market critically depends on whether the incumbent is interested in revealing or concealing her type to the product market. Hence, the occurrence of separating equilibrium or PE is endogenous. Similarly, in our paper, the emergence of the separating equilibrium or PE depends on whether the regulator seeks to attract or deter entry, respectively.

the first stage, the regulator selects a subsidy s_1 and the monopolist responds by maximizing its profits,

$$\max_q (1-q)q - (c_{\text{inc}}^K - s_1)q$$

where c_{inc}^K denotes the incumbent's marginal costs for any type $K = \{H, L\}$, $1 > c_{\text{inc}}^H > c_{\text{inc}}^L \geq 0$, and $P(q) = 1 - q$ is the inverse market demand. In the second stage, a potential entrant decides whether or not to join. The regulator then revises his subsidy policy s_2 and, if entry occurs, firms compete as Cournot duopolists, simultaneously selecting production levels x_{inc} and x_{ent}, for the incumbent and entrant, respectively. Otherwise, the incumbent maintains its monopoly power during both periods. In addition, the entrant's marginal cost, c_{ent}, coincides with that of the high-cost incumbent, since it lacks experience in the industry.[13] The entrant must incur a fixed entry cost $F > 0$ which induces entry when the incumbent's costs are high, but deters it when they are low. Finally, the regulator's social welfare function in the first period is

$$\text{SW} = \lambda \text{CS}(q) + (1-\lambda)[\text{PS}(q) - s_1 q],$$

where $\text{CS}(q)(\text{PS}(q))$ denotes consumer surplus (producer surplus), $s_1 q$ is the government's total expenditure on subsidies, and λ represents the weight that the regulator assigns to consumer surplus. The second term, thus, reduces to $(1-q)q - c_{\text{inc}}^K q$. For compactness, let us use the normalization $\gamma \equiv \lambda/(1-\lambda)$, where $\gamma > 0$ represents the relative weight on consumer surplus.[14] Social welfare, hence, simplifies to $\gamma \text{CS}(q) + (1-q)q - c_{\text{inc}}^K q$.[15] A similar social welfare function applies to the second-period game. We next describe output and subsidies in the subgame perfect equilibrium of the game.

Lemma 1. *In the first period, the regulator sets a subsidy* $s_1^K = \gamma \frac{1 - c_{\text{inc}}^K}{2 - \gamma}$, *where* $K = \{H, L\}$, *and the incumbent responds with an output function*

13 If the entrant's costs were, instead, lower than those of the high-cost incumbent, $c_{\text{ent}} < c_{\text{inc}}^H$, the entrant would be willing to enter under larger parameter conditions, but would not qualitative affect our equilibrium results.

14 For generality, our model allows for $\gamma < 1$, which could arise if, for instance, the regulator holds stocks from the recently privatized monopoly (a common observation in certain underdeveloped countries, or highly corrupted regimes) and $\gamma > 1$ whereby the regulator assigns a larger weight to consumer than producer surplus.

15 The subsidy in our model is hence financed with non-distortionary taxes, as in Dixit and Kyle (1985). Otherwise, the marginal cost of raising public funds should enter into the regulator's social welfare function. Section 5.1 discusses that this consideration would shrink the set of parameter values sustaining some of our equilibrium results.

$q^K(s_1) = \frac{1-\left(c^K_{\text{inc}}-s_1\right)}{2}$, *which in equilibrium implies* $q^K(s_1^K) = \frac{1-c^K_{\text{inc}}}{2-\gamma} \equiv q^K_{\text{SO}}$. *Entry only occurs when the incumbent's costs are high. In the second period, if entry does not ensue (NE), the regulator maintains subsidies at* $s_2^{K,\text{NE}} = s_1^K$, *and the incumbent responds selecting* $x^{K,\text{NE}}_{\text{inc}}(s_2)$ *which coincides with* $q^K(s_1)$. *If entry occurs (E), the regulator sets a second-period subsidy* $s_2^{H,E} = \frac{(2\gamma-1)\left(1-c^K_{\text{inc}}\right)}{2(2-\gamma)}$ *and* $s_2^{L,E} = \frac{2\gamma-1+(2-\gamma)c^H_{\text{inc}}-(1+\gamma)c^L_{\text{inc}}}{2(2-\gamma)}$ *when the incumbent's costs are high and low, respectively, and firms respond producing* $x_i^{K,E}(s_2) = \frac{1-2c_i^K+c_j^K+s_2}{3}$ *where* $i = \{\text{inc}, \text{ent}\}$ *and* $j \neq i$. *In addition, subsidies and the resulting output levels are positive if and only if* $\gamma \geq 1/2$ *and firms' costs are not extremely asymmetric, i.e.* $\frac{1+(1-\gamma)c^L_{\text{inc}}}{2-\gamma} > c^H_{\text{inc}} > c^L_{\text{inc}}$.

Under monopoly, the regulator seeks to induce the socially optimal output level $q^K_{\text{SO}} \equiv \frac{1-c^K_{\text{inc}}}{2-\gamma}$, which is increasing in the weight on consumer surplus, γ, and decreasing in the incumbent's costs, c^K_{inc}. Therefore, the subsidy that induces this output level is also increasing in γ and decreasing in c^K_{inc}. Note that when the regulator assigns no weight to consumers, $\gamma = 0$, output level q^K_{SO} coincides with that of an unregulated monopoly, i.e. $\frac{1-c^K_{\text{inc}}}{2}$, whereas when $\gamma = 1$, the socially optimal output q^K_{SO} becomes the perfectly competitive output $1 - c^K_{\text{inc}}$.

Upon entry, the regulator seeks to induce the same socially optimal output at the aggregate level.[16] In this case, however, subsidy $s_2^{K,E}$ is not as generous as under monopoly, i.e. $s_2^{K,E} < s_2^{K,\text{NE}}$, since aggregate output under duopoly is closer to the social optimum.[17]

Therefore, under complete information, subsidy policy cannot be used by the regulator to promote or hinder entry, since the entry decision solely depends on the incumbent's costs. Under incomplete information, however, we next show that the informative content of subsidies can be used as a tool to deter entry. In particular, one might expect that subsidy policy could be used to attract rather than deter entry. However, our results show that regulator can have incentives to facilitate the incumbent's entry-deterring strategies when

16 Therefore, in a context of complete information, the regulator can induce socially optimal output level both with and without entry, thus implying that entry is socially undesirable for any entry cost $F > 0$. However, under a setting of incomplete information, we next show that this outcome does not necessarily hold for all entry costs.

17 In addition, the duopoly subsidy when the incumbent's costs are high, $s_2^{H,E}$, is positive for $\gamma > 1/2$, yielding a positive output for both firms. Since we aim at investigating the effects of subsidies on entry patterns, we hereafter focus on positive subsidies, i.e. $\gamma > 1/2$. If, in contrast, $\gamma < 1/2$, the subsidy would become zero, and firms would produce the standard duopoly output.

firms' costs are relatively symmetric (and thus subsidies give rise to small inefficiencies) and when, despite costs being asymmetric, the weight on consumer surplus is sufficiently large.

3 Signaling

Let us now analyze the case where the incumbent and regulator are privately informed about the incumbent's marginal costs. This information context describes settings where the social planner has accumulated information about the incumbent's cost structure over time, e.g. publicly managed monopolies that were recently privatized.[18] The entrant, however, does not observe the incumbent's cost and, hence, bases its entry decision on the observed first-period output level and subsidy. The time structure of this signaling game is as follows.[19]

1. Nature decides the realization of the incumbent's marginal costs, either high or low, with probabilities $p \in (0,1)$ and $1-p$, respectively. Incumbent and regulator privately observe this realization but the entrant does not.
2. The regulator sets a first-period subsidy s_1 and the incumbent responds choosing its first-period output level, $q(s_1)$.
3. Observing the pair of signals $(s_1, q(s_1))$, the entrant forms beliefs about the incumbent's marginal costs. Let $\mu(c_{\text{inc}}^H | q(s_1), s_1)$ denote the entrant's posterior belief about the incumbent's costs being high.
4. Given these beliefs, the entrant decides whether or not to enter the industry.

18 Assuming that the regulator was, instead, imperfectly informed about the incumbent's costs would not qualitatively affect our equilibrium results. It could nonetheless induce the regulator to use subsidy policy in order to conceal the incumbent's type under larger conditions, thus facilitating this firm's entry-deterring practices. In the context of environmental policy, Espinola-Arredondo and Munoz-Garcia (2014) consider a regulator who, despite being uninformed, has an informational advantage relative to the potential entrant and sets emission fees to curb pollution. Similarly as in our paper, they show that entry-deterring equilibria can be sustained in which emission fees facilitate the incumbent's concealment of information from potential competitors. However, such equilibrium emerges under larger conditions when the regulator is poorly informed about the incumbent's costs than when he perfectly observes its costs.

19 To facilitate the comparison of our results with those of the literature on entry-deterrence games, e.g. Milgrom and Roberts (1982), we consider a similar information setting and time structure, whereby the incumbent's costs are unobserved by the potential entrant, but the entrant's can be anticipated by the incumbent given its experience in the industry.

5. If entry does not occur, the regulator sets a second-period subsidy, $s_2^{K,\text{NE}}$, and the incumbent responds producing $x_{\text{inc}}^{K,\text{NE}}(s_2^{K,\text{NE}})$. If, in contrast, entry ensues, the entrant observes the incumbent's costs and the regulator sets a second-period subsidy $s_2^{K,E}$. Both firms then compete as Cournot duopolists, producing $x_{\text{inc}}^{K,E}(s_2^{K,E})$ and $x_{\text{ent}}^{K,E}(s_2^{K,E})$.[20]

Hence, step 5 implies that information is revealed after entry, and all agents behave as under complete information. As a consequence, we hereafter focus on the informative role of first-period actions, as described in steps 1–4. For compactness, let D_{ent}^K denote the entrant's duopoly profits in equilibrium evaluated at subsidy $s_2^{K,E}$ when the entrant faces a K-type incumbent. As specified in the previous section, entry is unprofitable when the incumbent's costs are low, whereas it is profitable when costs are high, i.e. $D_{\text{ent}}^H > F > D_{\text{ent}}^L$, where F is the fixed entry cost.

3.1 Beliefs upon observing two signals

Since the potential entrant observes two signals (subsidy level and output) originating from two different agents, the specification of its beliefs are more intricate than in standard entry-deterrence games. In particular, we assume that beliefs must meet the following consistency requirements.

Consider a separating strategy profile in which the regulator facing a high (low)-cost firm selects $s_1^H(s_1^L)$ and the incumbent responds with output level $q^H(s_1^H)(q^L(s_1^L))$. In this setting, if the entrant observes an equilibrium strategy pair $(s_1^H, q^H(s_1^H))$, it believes that the incumbent's costs must be high, i.e. $\mu(c_{\text{inc}}^H | q^H(s_1^H), s_1^H) = 1$, and enters; while after $(s_1^L, q^L(s_1^L))$, the entrant's beliefs are $\mu(c_{\text{inc}}^H | q^L(s_1^L), s_1^L) = 0$, and stays out, where $(s_1^H, q^H(s_1^H)) \neq (s_1^L, q^L(s_1^L))$. Let us now examine off-the-equilibrium beliefs. First, if the regulator chooses an equilibrium subsidy s_1^H but the incumbent deviates to an off-the-equilibrium output $q(s_1^H)$, where $q(s_1^H) \neq q^H(s_1^H), q^L(s_1^H)$, the entrant only relies on the signal of the non-deviating player (the regulator). Following the notion of "unprejudiced beliefs" by Bagwell and Ramey (1991) and Schultz (1999), we assume that the

20 Espinola-Arredondo, Munoz-Garcia, and Bayham (2014) show that, in the context of environmental policy, the use of emission fees which cannot be revised across periods still gives rise to equilibrium outcomes in which the regulator facilitates the incumbent's concealment of information from potential entrants, thus promoting entry-deterring practices. Such entry-deterring equilibrium, nonetheless, emerges under larger conditions when regulation remains unaffected across time than when it can be rapidly revised, as that considered in our paper.

entrant's beliefs are compatible with the strategy selected by the non-deviating player, and hence $\mu(c_{\text{inc}}^H|q(s_1^H), s_1^H) = 1$, thus attracting entry.[21] Analogously, after strategy pair $(s_1, q^K(s_1))$, in which the regulator now selects the off-the-equilibrium subsidy s_1, where $s_1 \neq s_1^H, s_1^L$, but the incumbent responds with equilibrium strategies, the entrant bases its entry decision on the incumbent's signal alone, i.e. $\mu(c_{\text{inc}}^H|q^H(s_1), s_1) = 1$ and $\mu(c_{\text{inc}}^H|q^L(s_1), s_1) = 0$. Second, if the regulator sets an equilibrium subsidy of s_1^H, but the high-cost incumbent imitates the output function of the low-cost firm, $q^L(s)$, the entrant observes equilibrium signals corresponding to two different types of incumbents. In this case, the entrant is in the dark: is the deviation originating from the high-cost incumbent, who mimics the output function of the low-cost firm, $q^L(s_1)$, in order to deter entry? Or, is it coming from a regulator facing a low-cost incumbent, who chooses s_1^H in order to attract entry? According to unprejudiced beliefs, the entrant cannot discern the incumbent's costs with certainty, and thus cannot assign full probability to either type, i.e. $\mu(c_{\text{inc}}^H|q^L(s_1^H), s_1^H) = \mu' \in (0, 1)$. Finally, when both regulator and incumbent select type-independent strategies, the entrant cannot update its beliefs upon observing subsidies and output, and the use of unprejudiced beliefs does not restrict the entrant's beliefs. Hence, we apply the Cho and Kreps' (1987) Intuitive Criterion to limit the set of PEs with reasonable beliefs.[22]

The following section focuses on strategy profiles where both regulator and incumbent select type-dependent strategies and, thus, private information is conveyed to the entrant. Because both informed agents choose separating strategies, we refer to this type of profiles as two-sided separating equilibria. (Appendix 2 analyzes profiles where only one agent, either the regulator or the incumbent, chooses a type-dependent strategy, which we refer as one-sided separating equilibria.) Finally, we analyze strategy profiles in which both incumbent and entrant select type-independent strategies, i.e. PEs, and thus the entrant cannot infer the incumbent's type.

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21 A similar argument is applicable to strategy pair $(s_1^L, q(s_1^L))$, where the entrant solely relies on the regulator's actions and, hence, $\mu(c_{\text{inc}}^H|q(s_1^L), s_1^L) = 0$, deterring the entrant from the industry.

22 The application of Cho and Kreps' (1987) Intuitive Criterion to the setting we analyze, with two signals, follows that in Schultz (1996, 1999). In particular, if the entrant observes an off-the-equilibrium message, and such a message is equilibrium dominated when the incumbent's costs are high, but undominated when they are low, then the only incumbent who could benefit from sending such an off-the-equilibrium message is the low-cost firm. As a consequence, the entrant should believe that the incumbent's costs must be low.

4 Separating equilibrium

The following proposition shows that a separating equilibrium can be sustained where players behave as under complete information.

Proposition 1. *A two-sided separating equilibrium (TS) can be supported in which the regulator chooses the complete information type-dependent subsidy pair* $\left(s_1^H, s_1^L\right)$*, and the incumbent responds choosing the complete information type-dependent output pair* $\left(q^H(s_1), q^L(s_1)\right)$*. This equilibrium can be sustained when the entrant's off-the-equilibrium beliefs* $\mu(c_{\text{inc}}^H | q^L(s_1^H), s_1^H) = \mu'$ *are sufficiently high, i.e.* $\mu' \geq \mu_1 \equiv \frac{F - D_{\text{ent}}^L}{D_{\text{ent}}^H - D_{\text{ent}}^L}$*, for any production costs. If, in contrast,* $\mu' < \mu_1$*, this equilibrium exists if firms' costs are sufficiently asymmetric, i.e.* $c_{\text{inc}}^H > \overline{\alpha} \equiv \frac{\sqrt{3\delta}+(2-\gamma)c_{\text{inc}}^L}{\sqrt{3\delta}+2-\gamma}$.

Let us first examine the case in which off-the-equilibrium beliefs satisfy $\mu' \geq \mu_1$. Hence, upon observing contradictory signals $(s_1^H, q^L(s_1^H))$, the entrant's beliefs prescribe that the incumbent's costs are likely high, thus attracting it to the industry. In this setting, the high-cost firm cannot deter entry by mimicking the output decision of the low-cost incumbent, $q^L(s_1^H)$. Similarly, the regulator does not deviate from equilibrium strategies, since the TS yields optimal output levels, while deviations would entail inefficiencies, and thus the TS can be sustained for all cost parameters. In contrast, when the entrant's beliefs are relatively low, $\mu' < \mu_1$, the entrant responds staying out after observing contradictory signals $(s_1^H, q^L(s_1^H))$. In this context, the high-cost incumbent could successfully deter entry by imitating the low-cost firm, $q^L(s_1^H)$, but such overproduction effort becomes too costly when $c_{\text{inc}}^H > \overline{\alpha}$, thus inducing the incumbent to behave as under complete information.[23]

The next corollary compares equilibrium welfare relative to two benchmarks: that arising under a complete information setting when the regulator is present, $W_{\text{CI}}^{R,L}$, and that in the separating equilibrium of a signaling game where the regulator is absent, $W_{\text{SE}}^{\text{NR},L}$, as in Milgrom and Roberts (1982).

Corollary 1. *Social welfare in the separating equilibrium,* $W_{\text{SE}}^{R,L}$*, coincides with that under complete information,* $W_{\text{CI}}^{R,L}$*, and it is weakly larger than that arising in signaling games where the regulator is absent,* $W_{\text{SE}}^{\text{NR},L}$.

23 Because unprejudiced beliefs allow for $\mu' \in (0,1)$, this equilibrium result still holds when the entrant's beliefs upon observing contradictory signals approach zero or one, i.e. the entrant has a "prejudice" in favor of the low- or high-cost incumbent, respectively.

Since subsidy and output levels under the TS coincide with those in complete information settings, both information contexts yield the same welfare level; a non-distortionary result similar to that in models where the potential entrant observes signals originating from two incumbent firms, such as Bagwell and Ramey (1991) and Schultz (1999). However, unlike signaling models where the regulator is absent, the presence of the regulator guarantees the production of the socially optimal output q_{SO}^{K} during both periods, entailing a higher social welfare, i.e. $W_{SE}^{R,L} > W_{SE}^{NR,L}$. (Recall that Appendix 2 shows that strategy profiles where only one agent selects a type-dependent strategy cannot be sustained in equilibrium.)

5 Pooling equilibrium

In this section, we examine settings in which both regulator and incumbent choose a type-independent strategy and, therefore, no information is conveyed to the entrant.

Proposition 2. *A PE can be supported in which the regulator selects a type-independent subsidy s_1^L, the incumbent responds with a type-independent output function $q^L(s_1)$, and entry does not ensue, if priors satisfy $p \leq \bar{p}$, and entry costs are high, $F > F(\gamma)$, where $F(\gamma) \equiv \frac{\left(c_{inc}^H - c_{inc}^L\right)^2}{2(2-\gamma)}$. In addition, for admissible entry costs $D_{ent}^H > F > D_{ent}^L$, $F > F(\gamma)$ implies that $\gamma > \bar{\gamma}$, where $\bar{\gamma} \equiv 2 - \frac{\left(1-c_{inc}^H\right)^2}{2\left(c_{inc}^H - c_{inc}^L\right)^2}$.*

The high-cost incumbent exerts an overproduction effort in order to mimic the low-cost firm, raising its output function from $q^H(s_1)$ to $q^L(s_1)$ as depicted in Figure 1. The regulator, in addition, chooses a type-independent subsidy s_1^L, rather than that under complete information s_1^H, i.e. he over-subsidizes. Hence, the entrant cannot infer the incumbent's type and stays out of the industry given its low priors.[24]

Let us next examine the regulator's incentives to set subsidy s_1^L. On the one hand, setting such a suboptimal subsidy generates a welfare loss, since the induced output $q^L(s_1^L)$ is larger than the optimal output q_{SO}^H. This welfare loss,

24 Note that if, instead, the regulator chose a subsidy s_1^B inducing the optimal output for this type of incumbent, q_{SO}^H, the entrant would infer the incumbent's cost and enter, thus eliminating the high-cost firm's incentives to overproduce.

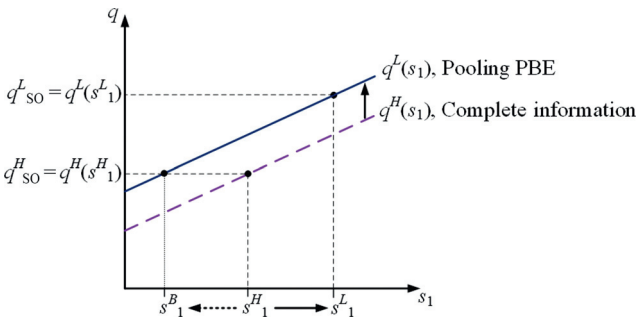

Figure 1: Pooling equilibrium

however, becomes smaller as the regulator assigns a larger weight on consumer surplus. On the other hand, the subsidy deters entry, thus entailing savings in the entry costs, F, i.e. a welfare gain. Therefore, the regulator is willing to set s_1^L when the savings in the entry costs are relatively large, i.e. $F > F(\gamma)$. In this setting, the welfare gains offset the losses, ultimately yielding a larger social welfare than under complete information.

In addition, cutoff $F(\gamma)$ is increasing in γ. Intuitively, when the welfare loss from overproduction is relatively small (high γ) and the savings in entry costs are sufficiently large (high F), the regulator's preferences for entry deterrence are aligned with the incumbent's. In this context, the regulator sets s_1^L, which facilitates the incumbent's entry-deterring practices. Otherwise, the regulator assigns a small weight on consumer surplus, $\gamma \leq \bar{\gamma}$, and the welfare loss from overproduction generates large inefficiencies. In this case, the regulator's and incumbent's preferences are misaligned, since the former prefers to behave as under complete information, setting a subsidy s_1^H, which ultimately attracts entry. The following corollary examines how cost symmetry affects the emergence of the PE.

Corollary 2 (Cost symmetry). *When firms' costs are relatively symmetric, i.e.* $C_2 > c_{\text{inc}}^H$, *and therefore, the PE can be supported for all values of* γ. *In addition, when* $C_1 \geq c_{\text{inc}}^H > C_2$, *cutoff* $\bar{\gamma}$ *satisfies* $\bar{\gamma} \in [1/2, 1]$ *and, hence, the PE exists for all* $\gamma > \bar{\gamma}$. *Finally, when costs are asymmetric, i.e.* $c_{\text{inc}}^H > C_1$, *cutoff* $\bar{\gamma}$ *satisfies* $\bar{\gamma} > 1$.

Corollary 2 shows that the PE can be sustained under larger parameter values when firms' costs are symmetric. Figure 2 illustrates this result. Specifically, the welfare loss that arises from the incumbent's mimicking effort diminishes as costs become more symmetric, thus expanding the set of parameters under

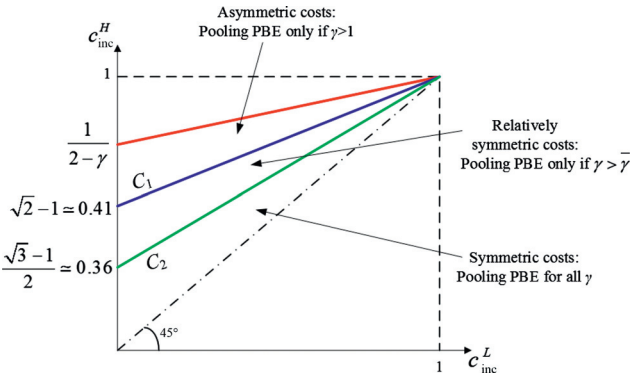

Figure 2: Pooling equilibrium and cost symmetry

which this equilibrium can be supported. This result helps us evaluate the effects of cost-reducing policies which, for instance, support relatively inefficient firms in their installation of new technologies. In particular, these policies would entail a reduction in the cost asymmetry between firms, ultimately facilitating the emergence of the entry-deterring practices predicted by the PE. Let us next investigate if the presence of two signals restricts the parameter values under which the PE can be sustained.

Corollary 3 (Equilibrium conditions). *The set of production costs that support a PE when the regulator is present,* $c^H_{inc} \leq C_1$*, also sustains this equilibrium when he is absent,* $c^H_{inc} \leq C^{NR}_{PE}$*, where* $C_1 < C^{NR}_{PE}$ *and* $C^{NR}_{PE} \equiv \frac{9c^L_{inc}-3(1-c^L_{inc})\sqrt{5}-5}{4}$.

Intuitively, the presence of two informed agents that can convey information hinders the emergence of PEs, relative to settings where a single player seeks to conceal information from the entrant. The PE with and without regulator can be sustained only when incumbent's costs are relatively symmetric, i.e. $c^H_{inc} \leq C_1$ and $c^H_{inc} \leq C^{NR}_{PE}$. However, in models where the regulator is absent, such symmetry condition arises because the high-cost incumbent is only willing to mimic the output decision of the low-cost firm when its overproduction effort is not very costly.[25] When regulation is present, in contrast, this condition emerges because of the inefficiencies that the regulator must bear. Specifically, he weighs the welfare loss that subsidy s^L_1 entails (which increases in the cost asymmetry)

25 Appendix 1 provides more details about the parameter conditions (i.e. cost asymmetry between the two types of firms) for which the PE can be sustained when the regulator is absent.

against the savings in entry costs, thus leading the regulator to select s_1^L only when firms' costs are relatively symmetric. The following corollary compares the welfare arising in this equilibrium with that when the regulator is absent.[26]

Corollary 4 (Welfare comparison). *Social welfare in the PE when the regulator is present, $W_{\text{PE}}^{R,H}$, is larger than that arising in signaling games where the regulator is absent, $W_{\text{PE}}^{NR,H}$, if $\gamma \geq \tilde{\gamma}$, where $\tilde{\gamma} \equiv \frac{4(c_{\text{inc}}^H - c_{\text{inc}}^L)(1-c_{\text{inc}}^L)}{2+(c_{\text{inc}}^H-2)c_{\text{inc}}^H+(c_{\text{inc}}^L-2)c_{\text{inc}}^L}$. In addition, (1) when firms' costs are symmetric, i.e. $C_4 \geq c_{\text{inc}}^H$, cutoff $\tilde{\gamma}$ satisfies $\tilde{\gamma} < 1/2$ and, therefore, $W_{\text{PE}}^{R,H} \geq W_{\text{PE}}^{NR,H}$ holds for all values of γ; (2) when costs are $C_3 \geq c_{\text{inc}}^H > C_4$, cutoff $\tilde{\gamma}$ satisfies $\tilde{\gamma} \in [1/2, 1]$ and, thus, $W_{\text{PE}}^{R,H} \geq W_{\text{PE}}^{NR,H}$ for all $\gamma \geq \tilde{\gamma}$; and (3) for asymmetric costs, $c_{\text{inc}}^H > C_3$, cutoff $\tilde{\gamma}$ satisfies $\tilde{\gamma} > 1$ and, hence, $W_{\text{PE}}^{R,H} < W_{\text{PE}}^{NR,H}$ holds if $\gamma < 1$, where $C_3 \equiv 3 - \sqrt{7}(1 - c_{\text{inc}}^L) - 2c_{\text{inc}}^L$ and $C_4 \equiv 5 - \sqrt{23}(1 - c_{\text{inc}}^L) - 4c_{\text{inc}}^L$.*

Under no regulation, the PE prescribes that the high-cost incumbent, despite increasing its production level to $q^L(0)$ in order to deter entry, still produces below the social optimum, i.e. $q^L(0) < q_{\text{SO}}^H$. This underproduction pattern continues in the second-period game, in which the incumbent produces its monopoly output $x_{\text{inc}}^{H,\text{NE}}(0)$. In contrast, when regulation is present, the incumbent produces a first-period output $q^L(s_1^L)$, which exceeds the social optimum q_{SO}^H. In addition, in the second period, the regulator induces an optimal output by setting s_1^H, i.e. $x_{\text{inc}}^{H,\text{NE}}(s_1^H) = x_{\text{SO}}^H$. Hence, if the weight on consumer surplus is high, the welfare loss arising from overproduction – when the regulator is present – is smaller than that emerging from underproduction – when he is absent – which entails that regulation becomes welfare improving.

Corollary 4 also shows that, when firms' costs are symmetric, the welfare loss arising from overproduction decreases and, hence, welfare is larger with than without regulator for all values of γ, i.e. the presence of the regulator is welfare improving. Figure 3 depicts this result. However, when costs become more asymmetric, such welfare loss is more substantial, and the PE entails a smaller welfare with than without regulator. In this context, the absence of regulation can, hence, be welfare superior. This result, however, does not entail that the regulator has incentives to set a zero subsidy to the incumbent when costs lie in region $C_1 > c_{\text{inc}}^H > C_3$. While welfare is larger in the PE when the

26 Corollary 4 does not compare social welfare in the PE with that under complete information since, for the PE to exist, it must yield a larger welfare level than in complete information.

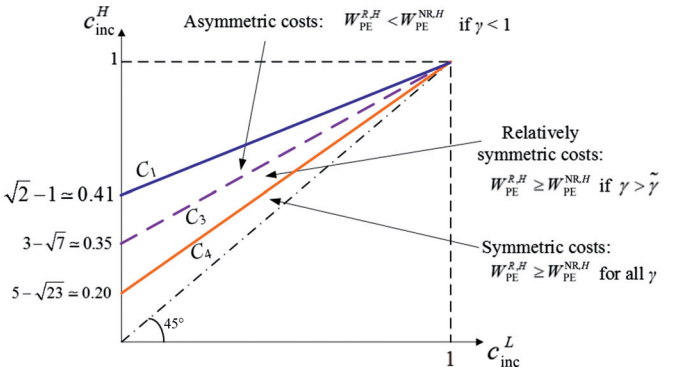

Figure 3: Pooling equilibrium with and without regulator

regulator is absent than when he is present, setting a zero subsidy would convey the incumbent's inefficient costs to the potential entrant, thus attracting entry.[27] This decision would thus give rise to two inefficiencies: an underproduction during the first-period game (when the incumbent produces its monopoly output without subsidies) and the fixed entry costs that reduce producer surplus during the second-period game. The regulator would increase social welfare if, instead, sets complete-information subsidies. While this policy also induces entry, it eliminates the first type of inefficiency mentioned above, as it yields socially optimal output levels during the first-period game. However, we know that in this context there is an alternative policy generating an even larger welfare: the subsidies in the PE of the game, which are welfare superior to complete-information strategies. Hence, the regulator has incentives to still behave as prescribed in Proposition 2 and set positive subsidies.

As a consequence, the welfare comparisons in Corollary 4 help predict in which contexts the presence of the regulator is more necessary; namely, when firms are relatively symmetric in costs. Our results, however, do not suggest that regulators, after being present in an industry, have incentives to strategically set a zero subsidy, since the information that such action reveals would ultimately yield a lower welfare than that under the PE examined in this section.

27 Note that the regulator does not have incentives to set a zero subsidy on the low-cost incumbent. Under PE subsidies, welfare is at the optimum, whereas setting zero subsidies in the first period would entail welfare losses emerging from underproduction in that period, and a costly entry in the second period.

6 Discussion and conclusions

Publicizing the incumbent's costs. At the beginning of the game, an informed regulator could have incentives to strategically disseminate information about the incumbent's costs to potential entrants by, for instance, publicizing its costs in different media outlets. This action would transform the information structure of the game, from one where the entrant is uninformed to a game where all agents are perfectly informed about the incumbent's costs. Our results nonetheless suggest that the regulator is not always willing to distribute such information. In particular, the regulator is only interested in publicizing information when his weight on consumer surplus is low and/or firms' costs are relatively asymmetric. Specifically, under these parameter conditions overall social welfare in the complete-information game exceeds that in the PE.[28] Otherwise, the regulator prefers to *not* publicize such information, thus supporting the incumbent's concealment of its type from the entrant, as predicted in the PE.[29] A similar argument can be used to evaluate the welfare consequences of distributing the statements, hearings, and so on, of those Senate and House committees which are in charge of designing subsidy policy. Our findings suggest that regulators with interests that are misaligned with those of incumbent firms would try to make this information publicly available, thus hindering firms' entry-deterring practices. Regulators whose preferences are aligned to the incumbent's would, in contrast, limit the dissemination of such information.

Regulation. Our results identify a strategic role of monopoly subsidies often overlooked by the literature on monopoly regulation. In particular, a monopoly subsidy – usually considered as a tool to induce the incumbent produce the socially optimal output – provides additional entry-deterrence benefits, thus increasing the extent of the incumbent's overproduction. The regulator anticipates this behavior when designing his subsidy policy and, in certain cases, he may strategically support the monopolist's concealment of information, thus deterring entry. Our results do not imply, however, that social welfare decreases by the presence of the regulator. In particular, while the regulator can facilitate

28 If, in contrast, parameter conditions support the emergence of the separating equilibrium, the regulator is indifferent between distributing information or concealing it, since equilibrium behavior, and welfare, coincides under both information contexts.

29 Such context describes a different setting than that in our paper, since the regulator is allowed to strategically choose whether or not to publicize the incumbent's type *before* setting s_1. Specifically, the sheer decision of the regulator of not distributing any information before the beginning of the game suggests that he must be facing a high-cost incumbent, since otherwise the regulator would have publicized the incumbent's type.

the monopolist ability to deter entry under certain cases, we show that his presence can actually be welfare improving.

Entry costs. Our results suggest that the PE is unlikely to arise in industries whose entry costs have experienced significant reductions, arising from technological or political reasons. Only the separating equilibrium would emerge in this case, whereby subsidy policy coincides with that under complete information, thus allowing the regulator to essentially ignore the information context in which firms operate. In contrast, if entry costs are high, the PE is more likely to arise. In this context, a regulator who ignored the information structure of the game, behaving as under complete information, would yield a suboptimal welfare level, $W_{\mathrm{CI}}^{R,H}$, rather than the higher $W_{\mathrm{PE}}^{R,H}$.

Alternative policy tools. The regulator could alternatively use entry costs, rather than first-period subsidies, in order to promote or hinder entry. In particular, by setting extremely high fixed entry costs, the regulator could hinder entry both when the incumbent's costs are low and high, and both when the potential entrant is informed and uninformed. In this context, the regulator could still achieve socially optimal output levels from the incumbent by setting the subsidy policy described in Lemma 1 when entry does not ensue. Therefore, the use of such alternative policy would simplify the game to one in which the entrant's access to information becomes irrelevant, as entry would be deterred both under complete and incomplete information, and in which the incumbent would not need to use its output decisions as an entry-deterring tool. Such a setting, however, is only possible if the regulator can set prohibitive entry costs, i.e. banning entry of new firms. If the regulator is not allowed to significantly increase entry costs (perhaps, because of international agreements), our analysis demonstrates that regulatory agencies can use existing subsidies to incumbent firms (not those offered to the potential entrants) as a policy that conveys or conceals information from entrants and ultimately promotes social welfare.

Distortionary taxation. Following Dixit and Kyle (1985), we consider that subsidies are raised using non-distortionary taxes. If, instead, production subsidies are raised with distortionary taxes, the social welfare function would include the deadweight loss from taxation, and the parameter values sustaining our equilibrium predictions would be affected. In the separating equilibrium, players behave as under complete information, but welfare levels would be lower than in our model. In contrast, the over-subsidization result predicted by the PE would be ameliorated, since the cost of raising public funds in this context is larger. Hence, this would ultimately shrink the region of parameter values for which the regulator helps the incumbent to conceal its type from the potential entrant.

Positive externalities. Our analysis can be easily extended to the regulation of products that generate positive externalities, e.g. hybrid cars and solar panels.

In particular, regulation under complete information would internalize the positive effects that these products generate, thus calling for a higher optimal output than in our current study, and thus larger subsidies. Under the PE, however, subsidies to this type of firms would exceed the social optimum. Nonetheless, if such over-subsidization occurs, our results suggest that it would be welfare improving.

Further research. The model provides extensions to other fields of economics. In particular, the monopolist's first-period actions do not generate externalities on other agents' payoffs. In several settings, however, governments use subsidies in order to promote (reduce) goods that impose positive (negative) externalities. An extension allowing for the presence of externalities could be modeled, for instance, by introducing the social benefit (or cost) of output in the regulator's social welfare function. Another venue of further research would consider contexts where the subsidy set in the first period is inflexible across time, i.e. it cannot be revised at the beginning of the second-period game. This regulatory setting describes countries whose legislative process is rigid, thus not allowing the regulator to rapidly adjust his second-period policy. Such inflexibility could affect the regulator's willingness to increase subsidies, as prescribed in the PE, since such subsidies would be permanent, thus imposing welfare effects across both periods.

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References

Albaek, S., and P. B. Overgaard. 1994. "Advertising and Pricing to Deter or Accommodate Entry When Demand Is Unknown: Comment." *International Journal of Industrial Organization* 12:83–87.

Amsden, A. 1989. *Asia's Next Giant: South Korea and Late Industrialization*. New York: Oxford University Press.

Bagwell, K., and G. Ramey. 1990. "Advertising and Pricing to Deter or Accommodate Entry When Demand Is Unknown." *International Journal of Industrial Organization* 8:93–113.

Bagwell, K., and G. Ramey. 1991. "Oligopoly Limit Pricing." *The RAND Journal of Economics* 22:155–72.

Bailey, J. 2006. "Subsidies Keep Airlines Flying to Small Towns." *The New York Times*, October 6.

Baron, D., and R. Myerson. 1982. "Regulating a Monopolist with Unknown Costs." *Econometrica* 50(4):911–30.

Cho, I., and D. Kreps. 1987. "Signaling Games and Stable Equilibrium." *Quarterly Journal of Economics* 102:179–222.

Daughety, A. F., and J. F. Reinganum. 2007. "Competition and Confidentiality: Signaling Quality in a Duopoly When There Is Universal Private Information." *Games and Economic Behavior* 58:94–120.

Daughety, A. F., and J. F. Reinganum. 2008. "Imperfect Competition and Quality Signaling." *Rand Journal of Economics* 39(1):163–83.

Dixit, A. K., and A. S. Kyle. 1985. "The Use of Protection and Subsidies for Entry Promotion and Deterrence." *American Economic Review* 75(1):139–52.

Espinola-Arredondo, A., and F. Munoz-Garcia. 2013. "When Does Environmental Regulation Facilitate Entry-Deterring Practices?" *Journal of Environmental Economics and Management* 65(1):133–52.

Espinola-Arredondo, A., and F. Munoz-Garcia. 2014. "Can Poorly Informed Regulators Hinder Competition." *Environmental and Resource Economics* Forthcoming.

Espinola-Arredondo, A., F. Munoz-Garcia, and J. Bayham. 2014. "The Entry-Deterring Effects of Inflexible Regulation." *Canadian Journal of Economics* 47(1):298–324.

Fluet, C., and P. Garella. 2002. "Advertising and Prices as Signals of Quality in a Regime of Price Rivalry." *International Journal of Industrial Organization* 20:907–30.

Friedrich, H. E., and B. L. Mordike. 2006. *Magnesium Technology: Metallurgy, Design Data, and Applications*. New York: Springer.

Gan, J., Y. Guo, and C. Xu. 2012. "What Makes Privatization Work? Evidence from a Large-Scale Nationwide Survey From China." Cheung Kong Graduate School of Business, Working Paper.

Gertner, R., R. Gibbons, and D. Sharfstein. 1988. "Simultaneous Signalling to the Capital and Product Markets." *The RAND Journal of Economics* 19:173–90.

Goolsbee, A., and C. Syverson. 2008. "How Do Incumbents Respond to the Threat of Entry? Evidence from the Major Airlines." *Quarterly Journal of Economics* 123(4):1611–33.

Harrington, J. E. Jr. 1986. "Limit Pricing When the Potential Entrant Is Uncertain of Its Cost Function." *Econometrica* 54:429–37.

Harrington, J. E. Jr. 1987. "Oligopolistic Entry Deterrence under Incomplete Information." *RAND Journal of Economics* 18(2):211–31.

Hertzendorf, M., and P. Overgaard. 2001. "Price Competition and Advertising Signals: Signaling by Competing Senders." *Journal of Economics and Management Strategy* 10:621–62.

International Energy Agency. 2010. *World Energy Outlook 2010*. Paris: OECD/IEA.

Kay, J., and D. J. Thompson. 1986. "Privatization: A Policy in Search of a Rationale." *Economic Journal* 96:18–32.

Laffont, J. J., and J. Tirole. 1986. "Using Cost Observation to Regulate Firms." *Journal of Political Economy* 94:614–41.

Levin, D., J. Peck, and L. Ye. 2009. "Quality Disclosure and Competition." *Journal of Industrial Economics* 57(1):167–96.

Lewis, T., and D. Sappington. 1989. "Countervailing Incentives in Agency Problems." *Journal of Economic Theory* 49:294–313.

Lieberman, M. 1987. "Excess Capacity as a Barrier to Entry: An Empirical Appraisal." *The Journal of Industrial Economics* 35(4):607–27.

Martin, S. 1995. "Oligopoly Limit Pricing: Strategic Substitutes, Strategic Complements." *International Journal of Industrial Organization* 13:41–65.

Milgrom, P., and J. Roberts. 1982. "Predation, Reputation, and Entry Deterrence." *Journal of Economic Theory* 27:280–312.

Milgrom, P., and J. Roberts. 1986. "Price and Advertising Signals of Product Quality." *Journal of Political Economy* 94:796–821.

OECD. 2009. "State Owned Enterprises in China: Reviewing the Evidence." OECD Working Group on Privatization and Corporate Governance of State Owned Assets.

Park, E. Y. 2003. "Behind Posco's Success." In *Manufacturing Competitiveness in Asia: How Internationally Competitive National Firms and Industries Developed in East Asia*, edited by K. S. Jomo. New York: Routledge Studies in the Growth Economies of Asia.

Ridley, D. B. 2008. "Herding versus Hotelling: Market Entry with Costly Information." *Journal of Economics and Management Strategy* 17(3):607–31.

Rosenbaum, D. I. 1998. *Market Dominance: How Firms Gain, Hold, or Lose It, and the Impact on Economic Performance*. Wesport, CT: Greenwood Publishing Group.

Schultz, C. 1996. "Polarization and Inefficient Policies." *Review of Economic Studies* 63:331–44.

Schultz, C. 1999. "Limit Pricing When Incumbents Have Conflicting Interests." *International Journal of Industrial Organization* 17:801–25.

Slocum, T. 2007. "The Failure of Electricity Deregulation: History, Status and Needed Reforms." Presented at the Federal Trade Commission Workshop Energy Markets in the 21st Century, Washington, DC.

U.S. Energy Information Administration. 2008. "Federal Financial Interventions and Subsidies in Energy Markets 2007." Report # SR/CNEAF/2008-01, April.

Waterson, M. 1988. *Regulation of the Firm and Natural Monopoly*. Oxford: Basil Blackwell.