Why do Firms Oppose Entry-Deterring Policies?

Environmental Regulation and Entry Deterrence

Ana Espínola-Arredondo[*]

School of Economic Sciences

Washington State University

Pullman, WA 99164

Félix Muñoz-García[†]

School of Economic Sciences

Washington State University

Pullman, WA 99164

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Abstract

This paper investigates the design of environmental regulation under different regimes: flexible and inflexible policies. We analyze under which settings strict emission fees can be used as an entry-deterring tool, and become socially optimal. Furthermore, we demonstrate that the incentives of social planner and the incumbent firm are aligned regarding policy regimes if entry can be easily deterred by setting a stringent regulation. Their incentives, however, can be misaligned when entry becomes more costly to deter, leading the incumbent to actually prefer environmental policies that attract entry.

KEYWORDS: Entry deterrence; Emission fees; Flexible and Inflexible policies.

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[*]Address: 111C Hulbert Hall, Washington State University, Pullman, WA 99164. E-mail: anaespinola@wsu.edu.

[†]Address: 103G Hulbert Hall, Washington State University. Pullman, WA 99164-6210. E-mail: fmunoz@wsu.edu. Phone: (509) 335 8402. Fax: (509) 335 1173.

1 Introduction

Recent studies have stressed the potential effects of environmental policy on market structure and competition, suggesting that environmental regulation hinders entry. In particular, those policies increase the initial investment that firms must incur in order to operate in the industry, such as OECD (2006) and Ryan (2012),[1] or allow for economies of scale to emerge in the compliance of environmental policy, ultimately entailing cost differentials between incumbents and entrants.[2] Nonetheless, to our knowledge, the analysis of how different environmental policy regimes affect entry has been overlooked by the existing literature. In this paper, we identify under which conditions policies that cannot be rapidly adjusted across time, while deterring entry, yield a larger welfare than policies that can be revised over time. Hence, our findings provide guidance for policy makers who regulate polluting industries subject to the threat of entry. Moreover, we show that environmental policies, despite deterring entry, might be opposed by incumbent firms.

Specifically, our study considers a social planner who sets emission fees on an industry, initially monopolized by an incumbent, and where an entrant may decide to join the market afterwards. We examine two given policy regimes that the regulator might face: a flexible policy, in which emission fees can be adjusted if the market structure changes; and an inflexible policy, in which the regulator does not have the ability to rapidly adjust environmental policy, i.e., fixed fee. Several environmental regulations in the U.S. are frequently revised. For instance, EPA (2001) indicates that wastewater discharge fees across most states have been raised approximately every year since 1986, exceeding the rate of inflation. Similarly, air emission fees in California have also experienced yearly changes since 1996. Other environmental policies, however, remain relatively constant across time, such as timber yield taxes and taxes on aviation noise pollution.[3,4] While our results provide welfare comparisons across regimes, our model does not allow the regulator to modify the policy regime in which he operates.

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[1] In particular, Ryan (2012) found that the Clean Air Act Amendments of 1990 increased the sunk entry cost by 35% in the market of Portland cement. He argues that, despite the increased profitability in this sector, few entrants chose to enter the industry.

[2] See, for instance, Ungson et al. (1985), Brock and Evans (1985), Dean et al. (2000) and Helland and Matsuno (2003). In this line of work, Monty (1991) and Dean and Brown (1995) report learning-by-doing effects in the compliance of environmental regulation, emphasizing the cost advantage of incumbent firms who are already familiarized with the administrative details of the policy. Such cost differential can be further augmented since environmental policy often places a heavier burden on new pollutant sources than on the incumbents'. Stavins (2005) provides a comprehensive survey on the impact of vintage-differentiation regulation.

[3] The design of timber yield taxes in California, for instance, has been unaffected since 1976, and the tax on aviation noise pollution in France has remained constant since 2003. Although these laws establish a baseline fee, they allow for annual adjustments based on factors such as inflation, property taxation, etc. However, these regulations have not been modified by the introduction of amendments that change such a baseline fee. For more details, see California State Board of Equalization's website, and the French Civil Aviation Authority (Environmental Report for 2008), respectively.

[4] For instance, the Canadian company Nova Scotia Power, publicly-owned until 1992, was regarded as a regional monopoly, since until recently local utility companies had to pay penalties for leaving the system. In addition, it was subject to an inflexible environmental policy, the Canadian Clean Air Act, initially passed in 1970 and not substantially modified until 2000. Similarly, the publicly-owned company Nigeria National Petroleum Corporation (NNPC) will soon be privatized, as reported in Bloomsberg Businessweek, December 3, 2013, and the industry is subject to the National Environmental Regulations, enacted in 2009.

Under an inflexible policy, initial fees are still enforced in the post-entry game. Therefore, this regulation can attract or deter entry when the regulator sets a relatively low or high fee, respectively. In contrast, when the regulator operates under a flexible policy, he cannot credibly deter entry, since he can revise emission fees if entry ensues. In an inflexible policy, the social planner must select a single emission fee, thereby producing inefficiencies in either one or both periods. We nonetheless show that the regulator can improve social welfare by strategically setting a significantly high fee that deters entry. In particular, relative to a flexible policy, the imposition of a stringent inflexible fee produces two opposite effects: first, it reduces monopoly output during both periods, but second, it generates savings in entry costs and environmental pollution. When the latter effect dominates the former, overall welfare increases, and therefore entry-deterrence becomes socially optimal. Otherwise, attracting entry is preferred and a flexible environmental policy yields a larger welfare. Our results hence suggest that countries where environmental regulation slowly adjusts to changes in industry conditions (inflexible regimes) could unintentionally hinder entry, yet they would generate a larger social welfare than by the implementation of policies that attract entry.

Finally, we investigate whether the incumbent's profits are negatively affected by emission fees that deter entry, thus identifying under which conditions the incumbent would actually oppose these entry-deterring fees. An inflexible policy allows the incumbent to maintain its monopoly power, but reduces profits across time. Specifically, we show that, when entry is deterred by setting a high inflexible emission fee, the incumbent's benefits from monopolizing the industry are offset by the costs from bearing this fee, and hence the incumbent would lobby against an inflexible policy. We hence demonstrate that the regulator's and incumbent's interests are not necessarily aligned. In particular, when the regulator finds entry-deterrence socially optimal, the incumbent can oppose such a policy if the emission fee it bears is relatively high, i.e., the incumbent may actually prefer that the regulator practices *less* entry deterrence.

Previous literature has analyzed the effect of environmental policy on firms' profits; such as Porter (1991) and Porter and van der Linde (1995a,b), who study how innovation practices are affected by regulation, and Farzin (2003), who examines the effects of environmental standards on product quality and its associated demand. These studies, however, overlook the entry-deterring consequences of environmental policy on the incumbent's profits.

Moreover, our paper relates to the literature on entry-deterrence games.[5] Since this literature often abstracts from the regulatory context in which firms operate, entry is only deterred if the incumbent seeks to discourage the newcomer. Our results, in contrast, predict settings where the regulator's practice of entry deterrence is actually opposed by the incumbent firm.[6]

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[5]This literature, initiated by Bain (1956) and Sylos-Labini (1962) for one incumbent, was then extended by Waldman (1987) to settings of incomplete information, and by Kovenoch and Roy (2005) to product-differentiated markets. In a reinterpretation of the quantity commitments considered in these papers on entry-deterrence, Spence (1977), Dixit (1980), Ware (1984) and Fudenberg and Tirole (1984), assume that incumbent firms commit to an investment in capacity, providing similar results.

[6]In a different information setting, Espinola-Arredondo and Munoz-Garcia (2013) analyze the regulator's role in helping the incumbent firm to conceal information from potential entrants, thus deterring entry. The paper, however,

In a related paper, Schoonbeek and de Vries (2009) also consider the role of environmental regulation in deterring entry. However, they assume that environmental policy is initially absent, and becomes only present in posterior stages, as if environmental regulation was newly introduced in that industry. Our model, by contrast, examines markets which were already subject to regulation, i.e., firms facing emission fees in all periods. This time structure gives rise to findings that did not emerge in Schoonbeek and de Vries (2009). In particular, in their article the incumbent firm is willing to bear a one-period stringent fee that deters entry in contexts in which the regulator does not find such a policy welfare improving. Our results, in contrast, show that the incumbent is less willing to bear such entry-deterring regulation during all periods, i.e., this firm actually opposes entry-deterring policies in settings in which the regulator finds welfare improving to deter entry. Hence, our paper suggests that firms in polluting industries that recurrently face environmental regulation will not favor environmental policy, as described in Schoonbeek and de Vries (2009), but instead would actively lobby against such a regulation. Finally, since entry deterrence is only feasible under inflexible policy regimes, we also examine a flexible policy, whereby the regulator can revise emission fees upon entry, providing welfare comparisons between these two regimes.[7]

The next section describes the model and time structure of the game. Section 3 examines the flexible policy regime, while section 4 investigates equilibrium fees under an inflexible policy. Section 5 compares the overall social welfare ensuing from the selection of different environmental policies. Section 6 evaluates the incumbent's profits under flexible and inflexible policies, and section 7 concludes.

2   Model

Consider an entry game with a monopolist incumbent, an entrant who decides whether or not to join the market (incurring an entry cost F) and a regulator who sets an emission fee per unit of output. If entry occurs, firms compete a la Cournot. In addition, firms face an inverse linear demand function $p(X) = 1 - X$, where X denotes aggregate output. The incumbent's and entrant's constant marginal costs are $0 \leq c < 1$. In particular, we study a two-stage complete-information game with the following time structure:

1. First period:

   1a. Under an *inflexible* policy regime, the regulator sets a constant fee t across time, i.e., non-adjustable fee. Under a *flexible* policy regime, he sets fee t_1 in the first period, but he is allowed to adjust it to t_2 at the beginning of the second period.

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does not consider inflexible policy regimes and, hence, it does not compare the preferences of regulator and incumbent regarding policy regimes.

[7]Ko et al. (1992) also compare flexible and inflexible environmental policies under a complete information context where a single incumbent produces stock externalities, i.e., pollution that does not fully dissipate across periods, without allowing for potential entry. Because entry cannot occur in their setting, the optimal policy path across periods mainly depends on the dissipation rate. In our model, in contrast, pollution fully dissipates across periods but entry may occur, thus affecting the social planner's optimal policy path with and without commitment.

1b. Given the first-period environmental policy, the incumbent responds selecting an output level, i.e., $q(t)$ under an inflexible policy or $q(t_1)$ under a flexible policy.

2. Second period:

2a. The entrant decides whether to enter the industry after observing the emission fee and the incumbent's marginal costs.

2b. The regulator maintains his environmental policy t if he is operates under an inflexible fee. Otherwise, he revises the policy from t_1 to t_2. In addition:

i. If entry does not occur, the incumbent responds producing a monopoly output $x_{inc}^{NE}(t)$ under an inflexible policy and $x_{inc}^{NE}(t_2)$ under a flexible policy; where subscript *inc* represents the incumbent, and superscript *NE* denotes no entry.

ii. If entry ensues, both firms compete as Cournot duopolists, producing $x_{inc}^{E}(t)$ and $x_{ent}^{E}(t)$ under an inflexible policy, and $x_{inc}^{E}(t_2)$ and $x_{ent}^{E}(t_2)$ under a flexible policy; where subscript *ent* denotes the entrant, and superscript E represents entry.

In the following section we examine fees and output levels in the flexible policy regime, as well as the resulting social welfare in equilibrium. Afterwards we analyze the inflexible regime, and finally compare social welfare under both policies. In addition, we next describe the demand function firms face and the social welfare function that the regulator uses to set optimal emission fees.

3 Flexible policy regime

3.1 Second-period game

No entry. If entry does not occur, the incumbent's profits when facing an inverse demand function $p(x_{inc}) = 1 - x_{inc}$ and a given fee t_2 are $\pi_{inc}^{NE}(x_{inc}) \equiv (1 - x_{inc}) x_{inc} - (c + t_2) x_{inc}$. The regulator's social welfare function in the second period is

$$SW_2^{NE} \equiv \ CS(x_{inc}) + \pi_{inc}^{NE}(x_{inc}) + T^{NE} - d \times (x_{inc})^2, \tag{3.1}$$

where $CS(x_{inc})$ represents the consumer surplus for a given output x_{inc}. In addition, T^{NE} is the tax revenue from collecting emission fees under no entry, and $d \times (x_{inc})^2$ represents the environmental damage from output, where parameter $d > 0$. The regulator induces the socially optimal output $x_{SO}^{NE} = \frac{1-c}{1+2d}$ by setting emission fee $t_2^{NE} = (2d - 1)x_{SO}^{NE}$, where $d \in \left[\frac{1}{2}, 1\right]$.[8] (For further details about equilibrium fees with and without entry, see Appendix 1).

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[8]Intuitively, this implies that the social planner assigns a moderate weight to environmental damage. If, instead, the environmental damage is extremely low, $d < 1/2$ (high, $d > 1$), the regulator would choose a subsidy, rather than a fee, in order to induce larger output levels (set an extremelly high fee to reduce output, respectively).

Entry. If entry occurs, firms compete as Cournot duopolists in the second period, producing an aggregate output of $X = x_{inc} + x_{ent}$. The regulator's social welfare function is $SW_2^E \equiv CS(X) + PS(X) + T^E - d \times X^2$, where $PS(X) \equiv \pi_{inc}^E(x_{inc}, x_{ent}) + \pi_{ent}^E(x_{inc}, x_{ent}) - F$ denotes producer surplus, and F is the fixed entry cost.[9] The regulator induces the same aggregate socially optimal output as without entry, i.e., $X_{SO}^E = \frac{1-c}{1+2d}$.[10] Specifically, the optimal second-period fee is $t_2^E = (4d-1)\frac{X_{SO}^E}{2}$ where $t_2^E > t_2^{NE}$, illustrating that the regulator sets more stringent fees to the duopolists than to the monopolist, as in Buchanan (1969). Finally, note that entry is profitable if emission fees are sufficiently low, but becomes unprofitable otherwise. That is, profit function $\pi_{ent}^E(t) = \frac{(1-c-t)^2}{9}$ originates above F, but falls below it for $t \geq \bar{t}$. For compactness, we refer to $\bar{t}$ as the "entry-deterring" fee, which solves $\pi_{ent}^E(t) = F$, i.e., $\bar{t} = 1 - c - 3\sqrt{F}$.[11]

3.2 First-period game

The regulator seeks to induce a first-period output q_{SO} that maximizes social welfare, which coincides with x_{SO}^{NE}. Hence, the first-period fee t_1 that induces the monopolist to produce q_{SO} coincides with that under no entry in the second period, i.e., $t_1 = t_2^{NE}$. Let $SW^E(t_1, t_2^E)$ represent the social welfare when entry occurs and the regulator sets fees t_1 and t_2^E. In particular, overall social welfare is $SW^E(t_1, t_2^E) = \frac{1-(2-c)c}{1+2d} - F$.

4 Inflexible policy regime

In the second-period game, firms face the same constant fee t selected in the first-period. Hence, we next analyze the regulator's setting of an optimal inflexible policy at the beginning of the game. In the case of no entry, the regulator seeks to induce the same optimal output in both periods, namely, q_{SO} and x_{SO}^{NE}. This can be achieved by a fee t^{NE}, which coincides with the optimal fee $t_1 = t_2^{NE}$ under a flexible policy. If entry occurs, however, the regulator needs to set different fees to the first-period monopolist than to the second-period duopolists in order to induce the socially optimal aggregate output. Any fee t that remains constant across time, therefore, produces a deadweight loss in one or both periods. Hence, in this setting the regulator minimizes the sum of the deadweight losses across both periods, choosing a fee t that solves

$$\min_{t} \ DWL_1(t) + DWL_2(t) \tag{4.1}$$

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[9] Entry costs F are considered by the regulator since he aggregates first- and second-period welfare. This is a modeling assumption common in the literature analyzing endogenous entry and their welfare effects; as in Mankiw and Whinston (1986, page 50), Kuhn and Vives (1999, page 585) and Ghosh and Morita (2007, page 546).

[10] For more details about the optimal regulation under entry and emission fee t_2^E, see Appendix 1.

[11] Therefore, $t_2^E < \bar{t}$ holds as long as entry costs are not very large, i.e., $F < \frac{(1-c)^2}{36}$; see the last section of Appendix 1. Under this condition, $\pi_{ent}^E(t_2^E) > F$, and entry is thus profitable in the equilibrium fee t_2^E. Note that this condition on entry costs, i.e., $\pi_{ent}^E(t_2^E) > F$, also embodies the standard assumption in entry-deterrence models where regulation is absent, in which F satisfies $\pi_{ent}^E(0) > F$, since $\pi_{ent}^E(0) > \pi_{ent}^E(t_2^E)$.

The deadweight loss in the first period is $DWL_1(t) \equiv \int_{q(t)}^{q_{SO}} \left[SMB^{NE}(q) - MD^{NE}(q) \right] dq$, where $SMB^{NE}(q)$ denotes the social marginal benefit of additional output, $MD^{NE}(q)$ represents the marginal environmental damage of output, and $q(t) = \frac{1-c-t}{2}$ is the monopoly profit-maximizing output for a given fee t. Figure 1a illustrates the first-period welfare loss of setting a fee t that differs from the socially optimal fee t_1. In particular, figure 1a depicts the case where $t > t_1$, leading to a monopoly output $q(t)$ that lies below the socially optimal output q_{SO}. Specifically, q_{SO} solves $SMB^{NE}(q) = MD^{NE}(q)$, and the emission fee that induces the monopolist to produce such an output level, t_1, is obtained from solving $PMB^{NE}(q_{SO}) = t$, where $PMB^{NE}(q)$ represents the incumbent's private marginal benefit of increasing output under no entry. (For further details about equilibrium fees under an inflexible regime, see Appendix 2).
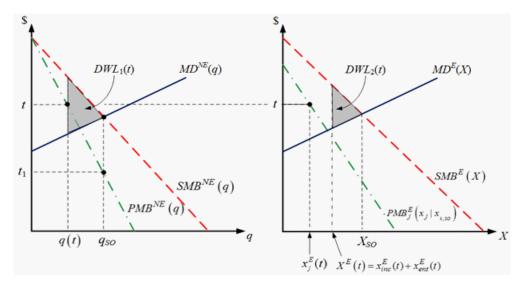

Fig 1a. First period welfare loss.　　　　　　Fig 1b. Second period welfare loss.

Similarly, the deadweight loss associated with tax t in the second period is given by $DWL_2(t) \equiv \int_{X^E(t)}^{X_{SO}^E} \left[SMB^E(X) - MD^E(X) \right] dX$, where $X^E(t) = x_{inc}^E(t) + x_{ent}^E(t)$ and $x_j^E(t)$ represents firm j's profit-maximizing output for a given fee t after entry. Deadweight loss $DWL_2(t)$ is depicted in figure 1b. Hence, when entry occurs, the optimal tax is a weighted average of first- and second-period taxes, $t^E = \frac{9}{25}t_1 + \frac{16}{25}t_2^E$, and thus $t_1 < t^E < t_2^E$. (This fee generates strictly positive production levels for both incumbent and entrant across periods; see Appendix 2 for further details.)[12]

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[12] An alternative inflexible policy regime could consider settings in which the regulator selects in the first period to all subsequent emission fees, t_1 and t_2. In this context, he would be able to avoid inefficiencies in the first-period game by establishing the monopoly fee t_1. In the second period inefficiencies can also be absent if he initially chooses a fee $t_2 = t_2^E$, which would attract entry; but emerge if he selects a fee $t_2 = \bar{t}$, which would deter entry. Inefficiencies are, hence, confined to the second period alone, thus making such a setting relatively close to that in Schoonbeek and de Vries (2009) whereby the regulator can only use second-period policies to deter entry.

4.1 Entry deterrence

In the context of an inflexible environmental policy, the regulator can select a relatively high fee $\bar{t}$ that deters entry, i.e., a fee that lowers the entrant's duopoly profits below his fixed entry cost F. Let $SW^{NE}(\bar{t})$ denote overall social welfare when the regulator sets a fee $\bar{t}$ that deters entry. Intuitively, the welfare cost of deterring entry arises from substantially reducing the incumbent's monopoly output across both periods, thereby decreasing consumer surplus and profits, whereas its welfare benefit emerges from the reduction in pollution and the savings in entry costs. In particular, the regulator can deter entry by setting fee $\bar{t} = 1 - c - 3\sqrt{F}$, which decreases as entry becomes more costly, thus facilitating entry deterrence; and it is positive for all $F < F^* \equiv \frac{(1-c)^2}{9}$. In addition, $\bar{t} > t_2^E$, as long as $F < \frac{(1-c)^2}{36}$. This fee yields an overall social welfare of $SW^{NE}(\bar{t}) = \frac{3\sqrt{F}[4-(3+6d)\sqrt{F}-4c]}{4}$, whereas the social welfare from setting an inflexible fee t^E that attracts entry is $SW^E(t^E) = \frac{49-49(2-c)c}{50(1+2d)} - F$.

The following lemma examines the regulator's incentives to set entry-deterring fees when the institutional setting is inflexible. (All proofs are relegated to the appendix.)

Lemma 1. *Under an inflexible policy regime, the social welfare from an entry-deterring fee $\bar{t}$, $SW^{NE}(\bar{t})$, exceeds that from setting a fee t^E that attracts entry, $SW^E(t^E)$, if and only if $F > F^{Inflex}(d)$. Furthermore, cutoff $F^{Inflex}(d)$ satisfies $F^{Inflex}(d) < \pi_{ent}^E(t^E)$, where*

$$F^{Inflex}(d) \equiv \frac{1310 + 8d(557 + 459d) - 60\sqrt{2}(1-c)^2 G - M(2-c)c}{25(5 + 28d + 36d^2)}$$

and $G \equiv \left[(1+2d)^3(205+18d)\right]^{\frac{1}{2}}$ and $M \equiv 2(1+2d)(655+918d)$. In addition, $\bar{t} > 0$ since cutoff F^* lies above $\pi_{ent}^E(t_2^E)$ for all parameter values.

Figure 2 represents cutoff $F^{Inflex}(d)$ for the case where $c = \frac{1}{4}$. Intuitively, when entry costs are higher than $F^{Inflex}(d)$, entry can be deterred by setting a low fee $\bar{t}$, thereby incurring a small welfare loss. For (F, d)-pairs below $F^{Inflex}(d)$, in contrast, entry deterrence becomes more difficult since it requires a high emission fee $\bar{t}$, thereby producing a large welfare loss. Hence, allowing entry is socially optimal.[13],[14]

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[13] For comparison purposes, figure 2 also includes the threshold under which entry costs are sufficiently high, making entry unprofitable under fee t_2^E, i.e., for all $F > \pi_{ent}^E(t_2^E)$ and entry is blockaded. Importantly, note that cutoff $F^{Inflex}(d)$ lies below the threshold for which entry is blockaded, allowing the regulator to practice entry deterrence if entry costs are intermediate.

[14] We consider a setting in which the potential entrant's decision to join the industry occurs in a relatively short time period, such as weeks or months; and thus assume that the discount factor, δ, approaches one. If, instead, entry occurred in a more distant time period, δ would decrease, leading the regulator to assign a small value to second-period welfare. Hence, when operating under an inflexible policy regime, the regulator would set a fee t^E that approaches that under a flexible policy regime t_1; as the regulator seeks to minimize the inefficiencies that mainly emerge during the first period. Furthermore, the regulator will now find that the setting of the entry-deterring fee $\bar{t}$ provides a heavily discounted welfare gain in the second period, which does not offset the first-period welfare loss that such a fee entails. Therefore, the regulator sets fee $\bar{t}$ under more restrictive conditions as δ decreases.
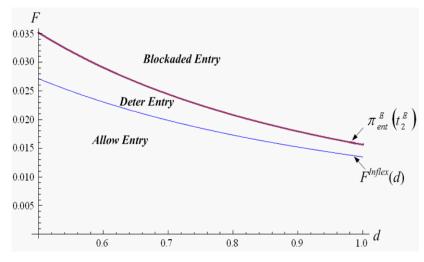
Fig 2. Entry patterns under an Inflexible regime.

5 Welfare comparisons across regimes

We can now evaluate the welfare properties of the two policy regimes. As described above, emission fees can be used as an entry-deterrence device when the regulator operates under an inflexible policy.

Let us introduce additional notation. Let $F^{Flex}(d)$ represent the entry cost that solves $SW^{NE}(\bar{t}) = SW^{E}(t_1, t_2^E)$. That is, the regulator is indifferent between selecting a stringent fee, $\bar{t}$, that deters entry under an inflexible regime and setting equilibrium fees that attract entry, (t_1, t_2^E), under a flexible policy. Figure 3 depicts such a cutoff, which lies above cutoff $F^{Inflex}(d)$ under all feasible values of d.[15] The following proposition summarizes the policy regime that yields the largest social welfare under different parameter conditions in the subgame-perfect equilibrium of the game. For presentation purposes, let region I represent entry costs where $F < F^{Inflex}(d)$ (see figure 3), region II the case in which $F^{Inflex}(d) < F < F^{Flex}(d)$, and region III denote the case where $F^{Flex}(d) < F < \pi_{ent}^{E}(t_2^E)$.

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[15] See proof of Proposition 1 for more details. To facilitate the comparison with figure 2, the figure also considers $c = \frac{1}{4}$. Different cost parameters yield similar comparisons, and can be provided by the authors upon request.
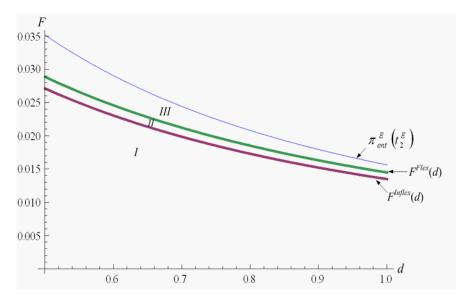
Fig 3. Welfare comparison between Flexible and Inflexible regimes.

Proposition 1. *In equilibrium, policy regimes satisfy:*

1. *In regions I and II, a flexible policy that attracts entry yields the largest welfare; and*

2. *In region III, an inflexible policy $\bar{t}$ that deters entry yields the largest welfare.*

The ranking of policy regimes can therefore be divided into three regions. When entry costs are sufficiently low, $F < F^{Inflex}(d)$, flexible regimes are socially optimal, since they yield a larger social welfare than an inflexible policy. This case is graphically represented in region I of figure 3. Intuitively, entry can only be deterred by selecting a relatively stringent fee $\bar{t}$, which reduces the incumbent's monopoly output during both periods, thus significantly decreasing consumer and producer surplus. As a consequence, the welfare loss from setting $\bar{t}$ offsets its associated savings in entry costs and environmental pollution, and a flexible environmental policy is welfare superior. A similar argument holds when entry costs are moderately low, $F^{Inflex}(d) < F < F^{Flex}(d)$ in region II, where flexible policies also yield a larger welfare.[16] When entry costs are relatively high, however, social welfare can be maximized by deterring entry. Specifically, in region III, entry can be deterred by imposing a relatively low $\bar{t}$, thereby incurring small welfare losses from reducing the incumbent's monopoly output. In this setting, an inflexible policy yields a larger social welfare.[17] Summarizing, our results suggest that inflexible environmental policies are particularly beneficial

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[16] The difference with region I arises off-the-equilibrium path since, if the regulator commits to a constant environmental policy, social welfare is now larger by setting an entry-deterrence fee $\bar{t}$ than by commiting to fee t^E.

[17] Finally, in the region where $F > \pi_{ent}^{E}\left(t_2^{E}\right)$, entry is blockaded and, hence, a flexible and inflexible policy yield the same social welfare.

10

in industries with high entry costs (such as cement, oil and gas, etc.), but flexible regimes are beneficial when entry costs are low.[18]

Finally, the region under which entry deterrence becomes socially optimal (region III) shrinks in firms' marginal costs. In particular, an increase in c produces a downward shift in the entrant's duopoly profits, $\pi_{ent}^E \left(t_2^E \right)$, reducing the distance $\pi_{ent}^E \left(t_2^E \right) - F^{Flex}(d)$. Intuitively, when the entrant is more inefficient, its profits upon entry decrease, making him less attracted to the market, and hence the regulator's task of deterring entry becomes less necessary.

6 Can entry-deterring policies be opposed by the incumbent?

From a policy perspective, stringent environmental policies that deter entry are commonly regarded as a policy instrument incumbent firms can favor. The next proposition shows, however, that in certain contexts the incumbent might actually lobby against the introduction of such entry-deterring regulation.

Proposition 2. *The incumbent's profits are larger when the regulator sets an entry-deterring fee $\bar{t}$ than under any other policy regime if and only if $F > F^{Profits}(d)$, where $F^{Profits}(d) \equiv \frac{1274(1-c)^2}{5625(1+2d)^2}$. Hence, the incumbent and regulator's preferences over the entry-deterring fee $\bar{t}$ are misaligned when $F^{Flex}(d) < F \leq F^{Profits}(d)$, but aligned when $F^{Profits}(d) < F \leq \pi_{ent}^E \left(t_2^E \right)$.*

In particular, fee $\bar{t}$ helps the incumbent maintain her monopoly power. However, given the stringency of $\bar{t}$, this fee significantly reduces her output and profits during both periods. As a consequence, the incumbent prefers that the regulator deters entry only when fee $\bar{t}$, and thus the profit loss that she must bear, is relatively small. This specifically occurs when entry is easy to deter, i.e., entry costs are relatively high. In order to illustrate this result, figure 4a superimposes cutoff $F^{Profits}(d)$ on figure 3, thus breaking the entry-deterring region III into two subareas: region IIIa, in which the regulator and incumbent's preferences are aligned, and region IIIb (shaded area), where preferences are misaligned. In particular, deterring entry is sequentially rational for the regulator in IIIb, but such a practice imposes a significant profit loss on the incumbent, thereby diminishing her overall profits. In summary, when entry costs are sufficiently high, both the regulator and the incumbent are willing to bear the cost of a stringent environmental policy in order to deter entry. In contrast, when entry costs are relatively low (in the shaded area), entry-deterrence becomes costly, implying that the incumbent prefers entry rather than bearing the large cost of the strict fee $\bar{t}$ that avoids entry (as depicted in figure 4b), whereas the regulator still finds entry-deterrence socially optimal.[19] In particular, figure 4b illustrates the duopoly fee t_2^E that the regulator would

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[18]Several rankings abound informing potential entrepreneurs about attractive industries with low entry costs. For instance, Enterpreneur.com lists commercial cleaning services on the top of their ranking, with start up costs ranging from \$3,000 to \$57,000.

[19]For consistency, figure 4b also considers $c = 1/4$, and assumes an environmental damage of $d = 0.6$. In this case, the depicted fees become $t_2^E = 0.238$, $\bar{t} = 0.75 - \sqrt{F}$, and $t_2^{NE} = 0.068$. In addition, evaluating cutoff $\pi_{ent}^E(t_E)$ at these parameter values we obtain 0.106, which is the upper bound of region III in the figure. At this point, the entry-deterring fee $\bar{t}$ reaches its minimum, 0.425, which still lies above $t_2^E = 0.238$.

set in regions I and II of figure 4a, where he allows entry; the entry-deterring fee $\bar{t}$ that he would set under region III; and the emission fee that the regulator sets in the context of blockaded entry, i.e., when $F > \pi_{ent}^{E}(t_2^E)$.
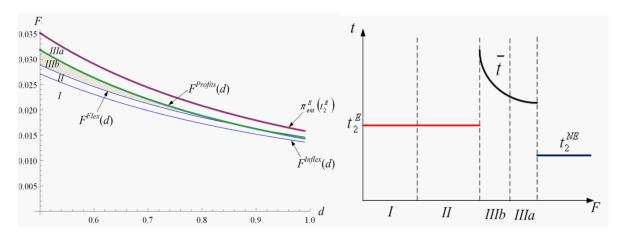

Fig 4a. Profits in the entry-deterring equilibrium.   Fig 4b. Emission fees in each region.

7 Conclusions

Our paper examines under which conditions governments may have incentives to set relatively stringent environmental policies in order to maximize social welfare. We show that entry deterrence becomes socially optimal when its associated welfare loss, due to setting a stringent fee across time which induces an inefficient production level, is smaller than its welfare gain, which arises from the savings in entry costs and environmental pollution. Otherwise, a flexible regime that attracts entry is welfare superior. In addition, we demonstrate that the incentives of the social planner and incumbent are not necessarily aligned regarding entry deterrence. In particular, under certain conditions the regulator finds it socially optimal to choose an inflexible policy that deters entry whereas the incumbent would actually prefer a flexible policy that attracts entry.

The paper assumes that the entrant observes the incumbent's cost before deciding whether to join the industry. In different settings, however, the entrant might not have access to this information, thereby using the incumbent's production decision and the regulator's environmental policy as signals in order to infer the incumbent's costs. While in a context without environmental regulation the incumbent can strategically use output decisions to convey or conceal information from the potential entrant, the introduction of emission fees could distort the incumbent's entry deterring behavior. In addition, we consider a single incumbent, which could be modified to allow for multiple incumbents; as in Gilbert and Vives (1986). Unlike their work, however, free-riding incentives are absent in our model since the incumbents' output choices do not condition entry decisions. Another extension to our model could consider that firms select not only their output

12

but that, for a given abatement technology, they also choose their abatement level. Finally, our paper can be extended to the analysis of non-polluting goods, such as solar panels. In this case, the regulator would not impose taxes but rather provide subsidies in order to induce firms to produce the socially optimal output.

8 Appendix

Appendix 1 - Flexible policy regime

No entry. Given a second-period fee t_2, under no entry the incumbent solves

$$\max_{x_{inc}} (1 - x_{inc})x_{inc} - (c + t_2) x_{inc}$$

which yields an output function $x_{inc}^{NE}(t_2) = \frac{1-(c+t_2)}{2}$. The social planner seeks to induce an output level that maximizes social welfare,

$$\max_{x_{inc}} CS(x_{inc}) + PS(x_{inc}) + T_2^{NE} - d \times (x_{inc})^2$$

where $CS(x_{inc}) \equiv \frac{1}{2}(x_{inc})^2$, $PS(x_{inc}) \equiv (1-x_{inc})x_{inc} - (c + t_2) x_{inc}$, denote consumer and producer surplus, respectively, and $T_2^{NE} \equiv t_2 x_{inc}$ represents tax revenue under no entry. Taking first-order conditions, we obtain the socially optimal output $x_{SO}^{NE} = \frac{1-c}{1+2d}$. Hence, the emission fee t_2 that induces the monopolist to produce x_{SO}^{NE} is that solving the equation

$$\frac{1 - (c + t_2)}{2} = \frac{1 - c}{1 + 2d},$$

i.e., $t_2^{NE} = (2d-1)\frac{1-c}{1+2d}$, or more compactly $t_2^{NE} = (2d-1)x_{SO}^{NE}$, which is positive for all $d > \frac{1}{2}$. (A similar fee, $t_1 = (2d-1)q_{SO}$, is implemented in the first period, since the incumbent is the unique firm operating in the market, where $x_{SO}^{NE} = q_{SO}^{NE}$)

Entry. In the case of entry, the incumbent (entrant) solves

$$\max_{x_{inc}} (1 - x_{inc} - x_{ent})x_{inc} - (c + t_2) x_{inc} \quad \text{and} \quad \max_{x_{ent}} (1 - x_{ent} - x_{inc})x_{ent} - (c + t_2) x_{ent} - F$$

respectively, yielding an output function $x_i^E(t_2) = \frac{1-c_i-t_2}{3}$ for any firm $i = \{inc, ent\}$. The social planner seeks to induce an output level X that maximizes

$$\max_X CS(X) + PS(X) + T_2 - d \times X^2$$

where $X \equiv x_{inc} + x_{ent}$, $CS(X) \equiv \frac{1}{2}(X)^2$, $PS(X) \equiv (1 - X)X - (c + t_2) X - F$, and $T_2 \equiv t_2 X$. Note that the producer surplus $PS(X)$ considers the incumbent's marginal costs. This is due to the fact that, in order to allocate the production decision of the socially optimal output, the social

13

planner equally splits it between incumbent and entrant, since both firms are equally efficient. Taking first-order conditions, we obtain the aggregate socially optimal output $X_{SO}^E = \frac{1-c}{1+2d}$, which coincides with x_{SO}^{NE}. Finally, in order to find fee t_2^E and individual output levels $x_{inc,SO}^E$ and $x_{ent,SO}^E$, the social planner must simultaneously solve

$$x_{inc,SO}^E + x_{ent,SO}^E = \frac{1-c}{1+2d} \tag{A.1}$$

(the sum of incumbent's and entrant's output coincides with the socially optimal output X_{SO}) and

$$x_{inc}^E(t_2) = \frac{1-c-t_2}{3}, \quad \text{and} \tag{A.2}$$

$$x_{ent}^E(t_2) = \frac{1-c-t_2}{3} \tag{A.3}$$

Simultaneously solving equations A.1-A.3, yields the emission fee $t_2^E = \frac{4d-1}{2}\frac{1-c}{1+2d}$, or $t_2^E = (4d-1)\frac{X_{SO}^E}{2}$, which is strictly positive if $d > \frac{1}{4}$, a condition that holds given that $d > \frac{1}{2}$ by assumption. Substituting fee t_2^E into the output function $x_i^E(t_2)$ yields $x_{inc}^E(t_2^E) = x_{ent}^E(t_2^E) = \frac{1}{2}\frac{1-c}{1+2d} = \frac{X_{SO}^E}{2}$, i.e., the socially optimal output is equally split among the incumbent and the entrant. ■

Entry-deterring fee. The entry-deterring fee $\bar{t}$ that solves $\pi_{ent}^E(t) = F$, i.e., $\frac{(1-c-t)^2}{9} = F$, is $\bar{t} = 1 - c - 3\sqrt{F}$. Such a fee is hence larger than the equilibrium fee under a flexible policy regime, t_2^E, as long as $c < 1 - 2(1+2d)\sqrt{F}$. This condition can be alternatively expressed as $F < \frac{(1-c)^2}{4(1+2d)^2}$. In addition, given that $d \in \left[\frac{1}{2}, 1\right]$, this cutoff starts at $F < \frac{(1-c)^2}{16}$ when $d = \frac{1}{2}$, and decreases in d, reaching $F < \frac{(1-c)^2}{36}$ when $d = 1$. Therefore, for $\bar{t} > t_2^E$ to hold under all admissible values of d, we need that entry costs satisfy $F < \frac{(1-c)^2}{36}$. ■

Appendix 2 - Inflexible policy regime

Let us first separately find the deadweight loss from setting a constant fee t in the first period, DWL_1, and in the second period, DWL_2. The first-period deadweight loss from setting an inefficient fee t is

$$DWL_1(t) \equiv \int_{q(t)}^{q_{SO}} \left[SMB^{NE}(q) - MD^{NE}(q)\right] dq$$

where socially optimal output q_{SO} is $q_{SO} = \frac{1-c}{1+2d}$, and the monopolist output function is $q(t) = \frac{1-(c+t)}{2}$. In addition, $SMB^{NE}(q) = (1-q) - c$, whereas $MD^{NE}(q) = 2dq$. Integrating, we obtain

$$DWL_1(t) = \frac{[(2d-1)c + 1 + t - 2d(1-t)]^2}{8A}$$

where $A \equiv 1 + 2d$. In the second-period game, the deadweight loss from the inflexible fee t is

$$DWL_2(t) \equiv \int_{X^E(t)}^{X_{SO}^E} \left[SMB^E(X) - MD^E(X)\right] dX,$$

14

where socially optimal output is still $X_{SO}^E = \frac{1-c}{1+2d}$, and $X^E(t) = x_{inc}^E(t) + x_{ent}^E(t)$, where $x_{inc}^E(t) = x_{ent}^E(t) = \frac{1-(c+t)}{3}$ represent the output function that each firm uses to respond to a given fee t under duopoly. Furthermore, $SMB^E(X) = (1-X) - c$, whereas $MD^{NE}(X) = 2dX$. Integrating, we obtain

$$DWL_2(t) = \frac{[(4d-1)c + 2 + 2t - 4d(1-t) - 1]^2}{18A}$$

The regulator can construct the sum $DWL_1(t) + DWL_2(t)$ (note that both $DWL_1(t)$ and $DWL_2(t)$ are strictly positive) and take first-order conditions with respect to t, obtaining fee $t^E = \frac{(1-c)[50d-17]}{25A}$. In addition, the emission fee t^E yields the minimum of the objective function $DWL_1(t) + DWL_2(t)$ since such a function is convex in t, i.e., $\frac{\partial^2[DWL_1(t) + DWL_2(t)]}{\partial t^2} = \frac{25A}{36} > 0$ for all parameter values.

Finally, fee t^E can be expressed as a linear combination of the equilibrium fees under a flexible policy, t_1 and t_2^E, by solving $t^E = \alpha t_1 + (1-\alpha)t_2^E$, where parameter α describes the relative weight on first-period taxes. Solving for parameter α yields $\alpha = \frac{9}{25}$. Hence, $t^E = \frac{9}{25}t_1 + \frac{16}{25}t_2^E$, and thus $t_1 < t^E < t_2^E$. From our analysis of the flexible policy, we know that fee t_2^E is positive and induces positive output levels from both firms in the industry. Therefore, a lower fee t^E in the inflexible policy regime must also induce positive production levels from both incumbent and entrant. ∎

Proof of Lemma 1

Under an inflexible policy regime, the social welfare from setting a constant entry-deterring fee $\bar{t} = 1 - c - 3\sqrt{F}$ is

$$SW^{NE}(\bar{t}) = \frac{3\sqrt{F}\left[4 - (3+6d)\sqrt{F} - 4c\right]}{4}$$

where the incumbent produces according to the monopoly output function $q(t) = \frac{1-c}{2}$ during both periods. If, in contrast, the regulator selects a constant fee t^E, entry ensues, yielding an overall social welfare of

$$SW^E(t^E) = \frac{49 - 49(2-c)c}{50(1+2d)} - F$$

Hence, the regulator prefers to deter entry, i.e., $SW^{NE}(\bar{t}) > SW^E(t^E)$, if $F > F^{Inflex}(d)$, where

$$F^{Inflex}(d) \equiv \frac{1310 + 8d(557 + 459d) - 60\sqrt{2}(1-c)^2 G - M(2-c)c}{25(5 + 28d + 36d^2)}$$

and $G \equiv \left[(1+2d)^3(205 + 18d)\right]^{\frac{1}{2}}$ and $M \equiv 2(1+2d)(655 + 918d)$. First, note that cutoff $F^{Inflex}(d)$ is decreasing in d for all costs $c \in (0,1)$. Second, cutoff $F^{Inflex}(d)$ lies below $F^* \equiv \frac{(1-c)^2}{9}$ for all admissible values of d, i.e., $d \in \left(\frac{1}{2}, 1\right)$. In particular, the highest point of cutoff $F^{Inflex}(d)$, $F^{Inflex}\left(\frac{1}{2}\right)$, is

$$\frac{557 - 30(1-c)^2\sqrt{214} - 557(2-c)c}{2450}$$

which is lower than $F^* \equiv \frac{(1-c)^2}{9}$, which is constant in d, for all costs $c \in (0,1)$. Third, cutoff $F^{Inflex}(d)$ also lies below the entrant's duopoly profits under the flexible fee t_2^E, $\pi_{ent}^E(t_2^E)$. Specifi-

15

cally, $\pi_{ent}^E(t_2^E) = \frac{(1-c)^2}{4(1+2d)^2}$ is decreasing in d, reaching its highest value at $d = \frac{1}{2}$, $\frac{(1-c)^2}{16}$, which lies above $F^{Inflex}\left(\frac{1}{2}\right)$; and reaches its lowest value at $d = 1$, $\frac{(1-c)^2}{36}$, which also lies above $F^{Inflex}(1)$. Fourth, note that the entrant's duopoly profits under the inflexible fee t^E, $\pi_{ent}^E(t^E) = \frac{196(1-c)}{625(1+2d)}$, satisfy $\pi_{ent}^E(t^E) > \pi_{ent}^E(t_2^E)$ since $t^E < t_2^E$, i.e., t^E is less stringent than t_2^E. Therefore, if $F^{Inflex}(d)$ satisfies $F^{Inflex}(d) < \pi_{ent}^E(t_2^E)$, then

$$F^{Inflex}(d) < \pi_{ent}^E(t_2^E) < \pi_{ent}^E(t^E).$$

Finally, note that profits $\pi_{ent}^E(t^E)$ lie below cutoff F^*. Indeed, $\pi_{ent}^E(t^E)$ reaches its highest point at $d = \frac{1}{2}$, $\frac{49(1-c)^2}{625}$, which is lower than cutoff F^*. Since F^* is constant in d, then $F^* > \pi_{ent}^E(t^E)$ under all parameter values. ∎

Proof of Proposition 1

Let us compare the social welfare that arises in the case that the regulator operates under a flexible regime or under an inflexible regime and, if so, whether he allows or deters entry. Entry ensues as long as the constant fee t does not exceed $\bar{t}$. In particular, overall social welfare from flexible emission fees t_1 and t_2^E is $SW^E\left(t_1, t_2^E\right) = \frac{1-(2-c)c}{1+2d} - F$, that of a constant fee t^E that allows entry is $SW^E\left(t^E\right) = \frac{49-49(2-c)c}{50(1+2d)} - F$, and that of an entry-deterring fee $\bar{t}$ is $SW^{NE}\left(\bar{t}\right) = \frac{3\sqrt{F}\left[4-(3+6d)\sqrt{F}-4c\right]}{4}$. It is straightforward to show that $SW^E\left(t_1, t_2^E\right) > SW^{NE}\left(\bar{t}\right)$ when $F < F^{Flex}(d)$, where

$$F^{Flex}(d) \equiv \frac{\psi - 48(1-c)^2(1+2d)^{3/2} - R}{(5+28d+36d^2)^2}$$

and $\psi \equiv 52 + 16d(11+9d)$ and $R \equiv 4(1+2d)(13+18d)(2-c)c$. In addition, $SW^{NE}\left(\bar{t}\right) > SW^E\left(t^{H,E}\right)$ when $F > F^{Inflex}(d)$, as described in Lemma 1, and $F^{Inflex}(d) < F^{Flex}(d)$. This implies that when $F < F^{Inflex}(d)$, social welfare satisfies $SW^E\left(t_1, t_2^E\right) > SW^E\left(t^E\right) > SW^{NE}\left(\bar{t}\right)$, and a flexible policy regime yields the largest social welfare; when $F^{Inflex}(d) < F < F^{Flex}(d)$, social welfare satisfies $SW^E\left(t_1, t_2^E\right) > SW^{NE}\left(\bar{t}\right) > SW^E\left(t^E\right)$, and a flexible policy still entails the largest social welfare; when $F^{Flex}(d) < F < \pi_{ent}^E\left(t_2^E\right)$, social welfare satisfies $SW^{NE}\left(\bar{t}\right) > SW^E\left(t_1, t_2^E\right) > SW^E\left(t^E\right)$, and an inflexible fee $\bar{t}$ that deters entry generates the largest welfare; and when $F > \pi_{ent}^E\left(t_2^E\right)$, entry is blockaded and both policy regimes yield the same social welfare. ∎

Proof of Proposition 2

The incumbent's profits when the regulator sets an entry-deterring fee $\bar{t} = 1 - c - 3\sqrt{F}$ are $\frac{9F}{4}$ during both the first and second period, where the incumbent produces according to the monopoly output function $q(t) = \frac{1-c-t}{2}$ during both periods, yielding an overall profit of $\frac{18F}{4}$.

If the regulator chooses a flexible policy regime, with equilibrium fees t_1 and t_2^E for the first and second-period, respectively, the incumbent's profits become $\frac{(1-c)^2}{(1+2d)^2}$ in the first period and $\frac{(1-c)^2}{4(1+2d)^2}$ in the second period (after entry ensues). Hence, overall profits are $\frac{5(1-c)^2}{4(1+2d)^2}$. Therefore, profits under

16

the entry-deterring fee $\bar{t}$ are larger than under the flexible fees $\left(t_1, t_2^E\right)$ for all $F > F^{Profits,Flex}(d)$ where $F^{Profits,Flex}(d) \equiv \frac{5(1-c)^2}{18(1+2d)^2}$.

If the regulator selects an inflexible policy regime, with equilibrium fee t^E, the incumbent's profits become $\frac{441(1-c)^2}{625(1+2d)^2}$ in the first period and $\frac{196(1-c)^2}{625(1+2d)^2}$ in the second period (after entry ensues). Hence, overall profits are $\frac{637(1-c)^2}{625(1+2d)^2}$. Therefore, profits under the entry-deterring fee $\bar{t}$ are larger than under the inflexible fee t^E for all $F > F^{Profits,Inflex}(d)$ where $F^{Profits,Inflex}(d) \equiv \frac{1274(1-c)^2}{5625(1+2d)^2}$.

In addition, note that cutoff $F^{Profits,Inflex}(d) > F^{Profits,Flex}(d)$, since the difference

$$F^{Profits,Inflex}(d) - F^{Profits,Flex}(d) = \frac{98(1-c)^2}{625(1+2d)^2}$$

is positive under all parameter values. Furthermore, $\pi_{ent}^E(t^E) > F^{Profits,Inflex}(d)$ since the difference

$$\pi_{ent}^E(t^E) - F^{Profits,Inflex}(d) = \frac{98(1-c)^2}{1125(1+2d)^2}$$

is positive under all parameter values. Therefore, $\pi_{ent}^E(t^E) > F^{Profits,Inflex}(d) > F^{Profits,Flex}(d)$. Hence, the region of parameter values under which the regulator prefers to practice entry deterrence but the incumbent does not occurs when $F \leq F^{Profits,Inflex}(d)$. Otherwise, both agents prefer the entry-deterring fee $\bar{t}$. Therefore, only cutoff $F^{Profits,Inflex}(d)$ is binding, and we denote $F^{Profits,Inflex}(d)$ as $F^{Profits}(d)$. ∎

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