Abatement Thresholds:

How Merger Prospects Affect Green Investments

Ana Espinola-Arredondo*, Felix Munoz-Garcia†, and Luis Gautier‡

October 17, 2025

Abstract

This paper studies how investments in abatement affect merger decisions. We show that aggregate abatement needs to reach a minimum threshold to induce a merger approval, which is analogous to public good games with threshold effects. This can provide firms with stronger incentives to invest in abatement than in traditional models, reducing net emissions, and requiring less stringent emission fees than in settings where firms do not face merger prospects. Our extensions explore different regulatory regimes, alternative timings, allowing for environmental research cartels, cost convexities, and spillovers, identifying in each case how mergers are affected.

KEYWORDS: Mergers, abatement, threshold effects, emission fees, policy asymmetries.
JEL CLASSIFICATION: D43, L13, L41, Q58.

*Address: 101B Hulbert Hall, Washington State University, Pullman, WA 99164. E-mail: anaespinola@wsu.edu.
†Address: 103H Hulbert Hall, Washington State University, Pullman, WA 99164. E-mail: fmunoz@wsu.edu.
‡Address: 3305-B, Facultad de Ciencias Económicas y Empresariales, Universidad de Malaga, Plaza del Eijido s/n. 29071 Málaga, Spain. E-mail: gautilui@uma.es.

1 Introduction

In several high-profile mergers, firms increased their green investments years before submitting merger requests —often independently of changes in environmental regulation. For instance, Siemens invested \$1.2 billion in offshore wind R&D during 2015-2016 prior to its April 2017 merger with Gamesa; see OffshoreWind (2017). Similarly, Danish company Ørsted, formerly a fossil-fuel-based utility, allocated \$1.5 billion to U.S. wind and solar projects in 2016 before merging with Lincoln Clean Energy in August 2018; see Bloomberg (2020). In the United States, Schneider Electric increased its investments in smart grid and energy efficiency technologies by \$800 million in early 2017 before merging with L&T Electrical & Automation in 2018.[1]

While firms often present these investments as part of broader sustainability strategies, we propose an alternative channel: firms may strategically increase green investments to influence antitrust evaluations and improve the likelihood of merger approvals. To explore this, we develop a sequential game where, in the first stage, firms independently choose their investment in abatement, which reduces their net emissions. In the second stage, the Environmental Protection Agency (EPA) responds to these investments setting a per-unit emission fee; in the third stage, firms decide whether to submit a merger request to the antitrust authority (AA); in the fourth stage, the AA evaluates the merger and responds approving or blocking it. For generality, we allow for the AA to ignore pollution in its merger guidelines, as in the United States, or consider environmental damages in its welfare comparisons, but assigning less weight than the EPA, as in the European Union, Australia, or Japan.[2]

A key feature of the model is the presence of an "abatement threshold": the AA approves a merger only if the industry's total abatement exceeds a minimum level. This introduces a strategic link between firms' environmental investments and the likelihood of merger approval. When the AA places a low weight on environmental damages—i.e., is highly asymmetric relative to the EPA—the abatement threshold becomes prohibitively high, discouraging firms from investing enough to trigger a merger. Conversely, when the AA's environmental valuation closely aligns with the EPA's, the threshold becomes trivially low, and mergers are always approved regardless of firms' abatement levels. Overall, when the AA and EPA are very symmetric or asymmetric, the abatement threshold does not affect firms' investment incentives. In contrast, when the AA assigns a moderate weight

[1] Other notable examples include Duke Energy, which invested approximately \$9 billion between 2005 and 2011 to expand its wind, solar, and biomass capacity and retire coal plants, preceding its 2012 merger with Progress Energy; see Duke Energy (2012); and Hitachi, which invested approximately \$1.9 billion between 2017 and 2019 in high-voltage direct current (HVDC) transmission systems and smart grid technologies before merging with ABB's Power Grids division in July 2020. Likewise, BP increased its investments in solar energy by \$200 million in 2016, before merging with Lightsource in December 2017. Finally, French multinational electric utility company ENGIE made targeted \$300 million in investments in electric vehicle charging infrastructure and smart energy systems in 2016-2017 before merging with EVBox, an EV charging solutions provider, in March 2017.

[2] The European Commission has acknowledged environmental considerations in cases like Norsk Hydro/Alumetal and Sika/MBCC, where mergers were seen to support decarbonization and innovation; see EC Competition Merger Brief (2023). Similar initiatives include merger guidelines in countries such as Japan, Germany, and Australia. In contrast, the U.S. Federal Trade Commission remains divided, with ongoing debate over whether environmental factors should influence competition policy; see Hanawalt et al. (2024).

to pollution, the threshold becomes binding.

To evaluate how merger prospects affect green investments, we compare two settings with EPA oversight: one with active antitrust enforcement (AA) and one without. When the AA is present, firms strategically adjust abatement to influence merger approval; absent the AA, such incentives vanish. We show that if the EPA and AA weigh environmental damages similarly, abatement remains unchanged. However, when their priorities diverge, the AA's presence increases both individual and aggregate abatement, lowering net emissions. In this context, merger oversight becomes environmentally beneficial by incentivizing firms to invest in green technologies and mitigating free-riding behavior.

Our results draw a close parallel with public good games featuring threshold effects. On one hand, a larger abatement induces less stringent emission fees —just like donations from one individual increase the total public good that other individuals can enjoy. On the other hand, greater abatement facilitates merger approvals —similar to threshold public good games, where contributions are only matched if aggregate donations meet a minimum threshold. While the former effect is well-known in the literature on abatement, the latter is unique to our setting and arises from the presence of the AA. In this context, the AA gives rise to an abatement threshold that attenuates free-riding incentives, ultimately inducing more investments and less emissions.

Our findings have implications for both environmental and merger policy. On the environmental side, we show that equilibrium abatement is weakly higher when firms anticipate the possibility of a future merger than otherwise, requiring a less stringent emission fee. In other words, an EPA that overlooks firms' incentives to increase abatement to influence merger approval would set a socially excessive fee, resulting in regulatory error and welfare losses. About merger policy, we find that, when the AA places a modest weight on environmental damages, its presence can enhance firms' incentives to invest in abatement. However, if the AA's environmental priorities closely align with those of the EPA, the abatement threshold becomes non-binding, and investment behavior remains unchanged. This suggests that *partial*—but not full—regulatory alignment between agencies may be the most effective approach to encourage green investments.

For comparison purposes, we explore how the timing of regulatory decisions affects abatement and merger approvals. When firms invest in abatement before the AA reviews the merger, they can strategically use these investments to affect the approval decision. In contrast, if the AA rules on the merger before abatement decisions are made, this strategic channel disappears, and mergers are blocked regardless of the AA's weight on environmental outcomes. This shows that when firms invest before the merger review, they are more likely to consider the regulatory threshold in their decisions.

We then test the robustness of our results to spillover effects, environmental research cartels, and convex production costs. When spillovers are present, a firm's investment in abatement benefits its rival, potentially reducing individual and aggregate investment incentives; a well-known result in the literature. However, we identify a new effect from spillovers, since they reduce the minimal abatement threshold inducing merger approvals. Comparing these two reductions, we show that mergers are facilitated by the presence of spillover effects if the minimal threshold decreases more significantly than aggregate abatement. Similarly, higher abatement costs reduce firms' investment, making it more difficult to meet the threshold for merger approval. These results imply that mergers are less likely to occur when green technologies are costly or when spillovers generate large free-riding incentives. Therefore, policy tools such as R&D subsidies can support mergers in polluting industries.

We also extend the analysis to settings where firms coordinate their abatement decisions through environmental research cartels (ERCs). Under no merger, ERCs lead to more abatement than in the non-cooperative case when pollution is mild, but less abatement otherwise —consistent with Poyago-Theotoky (2007). This changes the likelihood of a merger being approved in equilibrium: ERCs hinder mergers when pollution is low, but facilitate them when pollution is high. Under mergers, ERCs produce an unambiguous increase in abatement, as firms internalize output and abatement externalities, leading the EPA to respond with less stringent emission fees. Overall, ERCs may amplify the strategic role of abatement at inducing mergers, with their impact depending on pollution severity.

Related literature. Our model contributes to the intersection of environmental regulation and merger analysis. While prior work has studied environmental R&D, spillovers, and research cartels –see Poyago-Theotoky (2007), Lambertini et al. (2017), and Strandholm et al. (2025)– the effects of green investment on merger decisions remains unexplored. Our paper fills this gap by endogenizing market structure through merger activity and examining its impact on firms' abatement incentives.

We build on the merger policy literature under imperfect competition, initiated by Salant et al. (1983) and Farrell and Shapiro (1990), and extended to include environmental externalities by Montero (2002) and Fowlie and Reguant (2018). Fikru and Gautier (2016) and Gautier and Fikru (2024) further explore how environmental concerns and product differentiation shape merger incentives and welfare. Our contribution lies in modeling an AA that may assign less weight to environmental damages than the EPA, and analyzing how this asymmetry affects strategic investment.

A third strand of literature examines threshold public goods and strategic contributions—see Palfrey and Rosenthal (1984), Cadsby and Maynes (1999), and Barbieri and Malueg (2008). In our framework, aggregate abatement functions as a threshold public good, with firms motivated not only by regulatory costs but also by the prospect of merger approval.

Finally, our work relates to studies on policy coordination between environmental and competition authorities. Böhringer et al. (2017) and Fischer and Newell (2008) highlight the importance of aligning regulatory instruments, while Acemoglu et al. (2012) and Aghion et al. (2016) examine how policy design can steer innovation toward cleaner technologies. We extend this literature by showing how the timing and interaction of environmental and antitrust decisions shape firms' behavior. Choi et al. (2022) also study mergers in polluting industries, but do not allow for abatement investment or agency asymmetries. Extensions of our model with spillover costs connect to Katsoulacos and Xepapadeas (1996) and Poyago-Theotoky (2007), who analyze environmental policy under asymmetric information and the role of R&D spillovers.

The paper is organized as follows. Section 2 introduces the model. Section 3 analyzes the equilibrium outcomes. Section 4 explores other regulatory regimes, including settings without AA, without EPA, or with different time structures. Section 5 allows for three extensions to study the robustness of our results, namely, spillovers, environmental research cartels, and cost convexities, and section 6 concludes.

2 Model

Consider an industry with two firms facing inverse demand function $p(Q) = 1 - Q$, where Q denotes aggregate output, and interacting in the following sequential-move game:

1. In the first stage, every firm i independently chooses its investment in abatement (i.e., green investment), z_i, at a cost $\frac{\gamma(z_i)^2}{2}$, which is increasing and convex in z_i, and $\gamma > 0$ denotes firm i's investment efficiency (a lower γ indicates higher efficiency). The investment decreases firm i's per-unit emissions from $e_i = q_i$ to $e_i = q_i - z_i$. For simplicity, we consider no spillovers effects in abatement, but relax this assumption in section 5.1.

2. In the second stage, the environmental protection agency (EPA) sets a per-unit emission fee t.

3. In the third stage, firms choose whether to submit a merger request to the antitrust authority (AA).

4. In the fourth stage, the AA responds approving or blocking the merger.

5. In the fifth stage, firms compete à la Cournot (if no merger ensues) or coordinate their output decisions (if a merger ensues).

The EPA considers the following welfare function

$$W = CS + PS + T - ED$$

where $CS = \frac{Q^2}{2}$ denotes consumer surplus, $PS = \pi_i + \pi_j$ represents producer surplus, $T = tE$ is total tax collection so emission fees are revenue neutral, where $E = Q - Z$ denotes aggregate emissions and $Z = z_i + z_j$ represents aggregate investment in abatement, and $ED = dE^2$ denotes environmental damage, which is increasing and convex in aggregate emissions, E, and parameter d measures pollution severity, where $d \geq 1/2$ to avoid corner solutions.

The AA considers total welfare when evaluating mergers, but its environmental damage function is $ED_{AA} = d_{AA}E^2$, where parameter d_{AA} satisfies $0 \leq d_{AA} \leq d$. Our model embodies $d_{AA} = 0$ as a special case, where the AA ignores environmental considerations in its merger evaluation;

$0 < d_{AA} < d$, where the AA takes emissions into account but assigning less importance than the EPA; and $d_{AA} = d$, where both government agencies are symmetric in their objective functions. Therefore, for a given d, an increase in d_{AA} entails more symmetric agencies.

If the AA were to consider, instead, consumer surplus alone in its merger assessments, it is easy to show that, because mergers unambiguously reduce aggregate output, this agency would reject all merger requests. In that context, firms anticipate that investing more or less in abatement is inconsequential for the merger, since the AA rejects it in all settings, making its presence irrelevant. By considering total welfare, however, we show that abatement decisions can affect merger approvals.

3 Equilibrium analysis

We next solve the game by backward induction, starting in the last stage.

3.1 Fifth stage - Output decisions

The next lemma identifies equilibrium output under no merger (denoted with superscript NM), either because firms did not request it or because the AA blocks it; and under the merger (superscript M). For compactness, all proofs are relegated to the Appendix.

Lemma 1. *When the merger does not ensue, equilibrium output is* $q_i^{NM} = \frac{1-c-t}{3}$*, with profits* $\pi_i^{NM} = (q_i^{NM})^2 + tz_i$*. When the merger ensues, equilibrium output is* $q_i^M = \frac{1-c-t}{4}$*, with associated profits* $\pi_i^M = 2(q_i^M)^2 + tz_i$*.*

As expected, firms reduce their individual output after the merger, $q_i^M < q_i^{NM}$, which holds for all parameter values. As a consequence, aggregate output also decreases, from $Q^{NM} = 2q_i^{NM}$ to $Q^M = 2q_i^M$.

3.2 Fourth stage - Merger approval

At this stage, the AA anticipates output decisions. Using the welfare function presented in section 2, W_{AA}, the AA approves the merger if it increases welfare. As the following lemma shows, this occurs when the merger helps attenuate aggregate emissions. For simplicity, we consider that aggregate investments in abatement are not extreme, $Z < \frac{1-c}{2}$. Otherwise, the AA would approve all merger requests, for all parameter values, making this agency's role uninteresting.[3]

Lemma 2. *The merger is welfare improving,* $W_{AA}^M > W_{AA}^{NM}$*, if and only if*

$$d_{AA} \geq \overline{d}_{AA}(t, Z) \equiv \frac{5(1-c) + 7t}{2\left[7(1-c-t) - 12Z\right]},$$

[3] Propositions 1-3 below identify firms' investment in abatement in the first stage, showing that this condition on Z holds in equilibrium.

where cutoff $\overline{d}_{AA}(t,Z)$ *is unambiguously positive and increasing in* t, Z, *and* c.

While aggregate output decreases due to the merger, lowering welfare, aggregate emissions also decrease, improving welfare. As a consequence, the AA finds the merger welfare improving when the second effect dominates, which occurs if this agency assigns a sufficiently high weight to environmental damages, $d_{AA} \geq \overline{d}_{AA}(t,Z)$. In this case, the AA uses the merger as a tool to reduce total emissions. In contrast, when the AA assigns a low weight to environmental damages, $d_{AA} < \overline{d}_{AA}(t,Z)$, it blocks the merger. This embodies $d_{AA} = 0$ as a special case, where the AA, despite considering welfare pre- and post-merger, overlooks how the merger will affect pollution levels.

In addition, cutoff $\overline{d}_{AA}(t,Z)$ increases as the emission fee becomes more stringent (higher t) or firms invest more in abatement (higher Z). In both cases, the AA anticipates less emissions arising in equilibrium, making the emission-reduction associated with the merger less necessary.

This result entails that, when the EPA sets the emission fee in the second stage (as we examine below), choosing a more stringent fee induces more mergers being blocked by the AA in the fourth stage. At first glance, the EPA might seem to face a trade-off: setting stricter emission fees reduces pollution, but they also hinder mergers, which increases output and pollution. However, the EPA anticipates how the market structure will evolve and adjusts its policy accordingly. As a result, it selects emission fees that achieve socially optimal outcomes, regardless of whether a merger occurs.

3.3 Third stage - Merger request

In the third stage, firms anticipate the AA's approval decision according to Lemma 2. When $d_{AA} < \overline{d}_{AA}(t,Z)$, the AA rejects the merger and firms have no incentives to submit a request. Otherwise, the AA approves the merger, and firms submit a request if and only if their profits satisfy $\pi_i^M + \pi_j^M \geq \pi_i^{NM} + \pi_j^{NM}$. As shown in Lemma 3, this profit ranking always holds.

Lemma 3. *In the third stage, firms only have incentives to submit a merger request if* $d_{AA} \geq \overline{d}_{AA}(t,Z)$.

Therefore, firms submit a merger request in all contexts in which they anticipate the AA will respond approving it.

3.4 Second stage - Emission fee

The EPA anticipates equilibrium behavior in subsequent stages (Lemmas 2 and 3), setting the following emission fee.

Lemma 4. *If* $d_{AA} \geq \overline{d}_{AA}(t^M,Z)$ *holds, the EPA sets an emission fee* $t^M = \frac{(2d-1)(1-c)-4dZ}{2d+1}$, *which is positive for all* $d > d^M \equiv \frac{1-c}{2[(1-c)+2Z]}$, *increasing in* d, *but decreasing in* Z *and* c. *Otherwise, the EPA sets an emission fee* $t^{NM} = \frac{(4d-1)(1-c)-6dZ}{2(2d+1)}$, *which is positive for all* $d > d^{NM} \equiv$

$\frac{1-c}{2[2(1-c)-3Z]}$, *increasing in d, but decreasing in Z and c, and satisfies* $t^{NM} > t^M$ *for all parameter values.*

The fees with and without mergers exhibit similar comparative statics, namely, decreasing in aggregate abatement, as every unit of output generates fewer emissions; and in production costs because of lower output and emissions.

The ranking in emission fees, $t^{NM} > t^M$, indicates that the EPA anticipates firms generating less emissions when they merge, thus requiring a less stringent fee. Hence, the EPA's decision considers the AA's cutoff, $\overline{d}_{AA}(t, Z)$, evaluated at these two fees, which satisfies $\overline{d}_{AA}(t^{NM}, Z) > \overline{d}_{AA}(t^M, Z)$ since $\overline{d}_{AA}(t, Z)$ is increasing in t. As a consequence, these two cutoffs give rise to three regions, as depicted in figure 1: (i) when $d_{AA} < \overline{d}_{AA}(t^M, Z)$, the EPA anticipates that the AA will respond by rejecting the merger, both after fee t^M and t^{NM}; (ii) when $\overline{d}_{AA}(t^M, Z) \leq d_{AA} < \overline{d}_{AA}(t^{NM}, Z)$, the AA responds by approving the merger after the EPA sets fee t^M, but rejecting it after t^{NM}; and (iii) otherwise, the AA responds approving the merger, both after fee t^M and t^{NM}.

In region (i), the EPA's optimal fee is t^{NM}, which induces no mergers in subsequent stages. In region (iii), the EPA sets fee t^M, which induces a merger in next stages. In region (ii), however, the EPA could set a fee t^M, inducing a merger, or t^{NM}, which induces no mergers. This is because both fees induce the same aggregate output in equilibrium, $Q^{NM}(t^{NM}) = Q^M(t^M) = \frac{(1-c)+2dZ}{2d+1}$, yielding the same social welfare. Since the choice of fee does not affect welfare, we assume that the EPA sets fee t^M in regions (ii) and (iii)[4], and fee t^{NM} in region (i), implying that only cutoff $\overline{d}_{AA}(t^M, Z)$ is relevant at dividing these regions.[5] The next corollary identifies $\overline{d}_{AA}(t^M, Z)$ and its comparative statics.

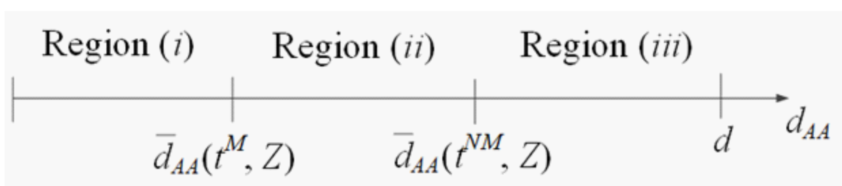

Figure 1. Cutoffs $\overline{d}_{AA}(t^M, Z)$ and $\overline{d}_{AA}(t^{NM}, Z)$.

Corollary 1. *Cutoff* $\overline{d}_{AA}(t^M, Z) = \frac{(1-c)(12d-1)-14dZ}{14(1-c)-4Z(3-d)}$ *is unambiguously positive, lies below d, and decreases in Z and c, but increases in d for all parameter values.*

The ranking between cutoff $\overline{d}_{AA}(t^M, Z)$ and d is particularly important. Indeed, $\overline{d}_{AA}(t^M, Z) < d$

[4] When the EPA is indifferent between t^{NM} and t^M, we consider that this agency selects the less stringent fee. This can be due to greater political acceptability or the lower administrative burden associated with implementing a less stringent policy.

[5] Other fees are not welfare maximizating for the EPA. To see this point, consider a fee $t' \neq t^{NM} \neq t^M$, which either satisfies $d_{AA} \geq \overline{d}_{AA}(t, Z)$ from Lemma 2, inducing the AA to approve the merger; or violates it, inducing the AA to respond rejecting the merger. In the former case, the fee that maximizes social welfare is t^M, while in the latter case it is t^{NM}. In other words, every fee t' induces a specific response from the AA and, given this response, the optimal fee is either t^M or t^{NM}.

entails that the AA approving the merger, which occurs when $d_{AA} \geq \overline{d}_{AA}(t^M, Z)$, is compatible with the AA assigning less weight to environmental damages than the EPA does, $d_{AA} \leq d$. If, instead, cutoff $\overline{d}_{AA}(t^M, Z)$ lied above d, then the merger could not be sustained in equilibrium regardless of the investment in abatement that firms choose in the first stage, since the AA cannot assign more weight on environmental damages than the EPA does.

In addition, the above corollary shows that the AA is more likely to approve the merger when the EPA sets a less stringent emission fee, which happens when firms invest more in abatement (higher Z), when its production is less efficient (higher c) or when pollution is less severe (lower d).

The comparative statics with respect to Z may seem surprising at first, since cutoff $\overline{d}_{AA}(t, Z)$ was increasing in Z in Lemma 2, when evaluated at a generic emission fee t; but now becomes decreasing in Z when evaluated at the optimal fee t^M, $\overline{d}_{AA}(t^M, Z)$. This occurs because fee t^M decreases more-than-proportionally to an increase in Z, i.e., $\frac{\partial t^M}{\partial Z} = -\frac{4d}{2d+1} < -1$. As a result, when firms increase their aggregate abatement, Z, the EPA lowers fee t^M by more than the increase in Z, making the emission-reduction effect of the merger *more* necessary. In figure 1, this result entails that cutoff $\overline{d}_{AA}(t^M, Z)$ shifts leftwards.

Alternatively, the merger approval condition $d_{AA} \geq \overline{d}_{AA}(t^M, Z)$ can be presented, after solving for Z, as follows

$$Z \geq Z^{Min} \equiv \frac{(1-c)(12d - 14d_{AA} - 1)}{2[7d + 2d_{AA}(d-3)]},$$

which is the minimum aggregate abatement that, as an industry, firms need to meet to induce a merger approval, i.e., abatement threshold. In the case that the AA ignores pollution, $d_{AA} = 0$, this threshold simplifies to $Z^{Min} = \frac{(1-c)(12d-1)}{14d}$, which is positive and increasing in d. Intuitively, the AA becomes more hesitant to approve mergers because a higher d leads to a more stringent emission fee, distorting aggregate output to a larger extent. To ameliorate this inefficiency, the AA requires firms to invest more in abatement, which lowers the emission fee, and increases aggregate output.

In contrast, when the AA assigns a positive weight on pollution, $d_{AA} > 0$, more stringent fees are viewed as less distortionary by this agency, requiring less investment in abatement (lower Z^{Min}). Informally, the AA sees the EPA's decisions as more distortionary when the AA assigns a low weight on pollution (i.e., agencies are asymmetric in their objective functions), but less distortionary otherwise.

Corollary 2. *The minimal aggregate abatement that induces a merger, Z^{Min}, is increasing in d, decreasing in d_{AA}, and positive for all $d_{AA} < \widehat{d}_{AA} \equiv \frac{12d-1}{14}$.*

Cutoff Z^{Min} is, then, decreasing in d_{AA}. Intuitively, as the AA and EPA become more symmetric in their weights on pollution, the merger is more likely to be approved. In contrast, Z^{Min} is increasing in d, implying that, as agencies are more asymmetric, the merger is less likely to be approved.

3.5 First stage - Investment decisions

At the beginning of the game, every firm i chooses its abatement level, z_i, anticipating the AA and EPA decisions in subsequent stages. This allows for aggregate abatement to exceed Z^{Min}, and thus induce a merger approval, or to fall short of Z^{Min}, leading to no merger. This implies that every firm can strategically use its own abatement decision to change the market structure. As a consequence, this setting is different from that in the literature on abatement decisions, where firms invest in z_i taking the market structure as given. Our model is, instead, analogous to that in public good games with "threshold effects," where every donor chooses her contribution to a charity anticipating that total contributions may meet or do not meet the threshold; see Palfrey and Rosenthal (1984), Cadsby and Maynes (1999), and Barbieri and Malueg (2008), among others.

More formally, this requires to separately analyze the case where a merger does not ensue (because aggregate abatement satisfies $Z < Z^{Min}$) and the case where a merger occurs (because $Z \geq Z^{Min}$).

For the analysis under no merger, for instance, we need to follow the next three steps. First, we find individual and aggregate abatement, z_i^{NM} and Z^{NM}. Second, we need to confirm that Z^{NM} is compatible with the initial condition, $Z^{NM} < Z^{Min}$, so a merger does not arise as required in this case. Third, we need to show that firm i has no unilateral incentives to deviate, which is more involved in the current setting. In the absence of threshold effects, firms take the market structure as given, implying that a mutual best response should be a Nash equilibrium of the first-stage game. When threshold effects are present, however, we also need to check that a firm has no incentives to increase its abatement above z_i^{NM} to induce an aggregate abatement that coincides with Z^{Min}, to strategically induce a merger. A similar argument applies to the case under a merger, finding z_i^M and Z^M, and following analogous steps.

No merger. If $Z < Z^{Min}$ holds, every firm i anticipates the EPA setting emission fee t^{NM}, and no merger unfolds in equilibrium. Then, each firm chooses its abatement level z_i to solve

$$\max_{z_i \geq 0} \ (q_i^{NM}(t^{NM}))^2 + t^{NM} z_i - \frac{\gamma}{2}(z_i)^2$$

which is evaluated at fee t^{NM}. For simplicity, we normalize the abatement efficiency parameter to $\gamma = 1$. Appendix 1 analyzes a more general setting where $\gamma \geq 0$ and Section 5.1 discusses how results are affected. Differentiating with respect to z_i, yields best response function

$$z_i^{NM}(z_j) = \frac{(1-c)[4d(2d+1)-1]}{4d\,(5+7d)+2} - \frac{d(3+4d)}{2d\,(5+7d)+1} z_j \tag{1}$$

indicating that firm i reduces its abatement when its rival's increases. An increase in z_j induces the EPA to respond with a less stringent emission fee, which every firm benefits from, i.e., positive externality. This externality is amplified when pollution is more severe (higher d), since the slope of the above best response function becomes steeper, implying that firms have stronger incentives to free-ride each others' abatement efforts.

The next proposition identifies investment in abatement in this setting.

Proposition 1. *When $Z < Z^{Min}$ holds, equilibrium abatement is $z_i^{NM} = \frac{(1-c)[4d(2d+1)-1]}{2(18d^2+13d+1)}$, which is positive for all admissible parameters, increasing in d but decreasing in c. In addition, $z_i^{NM} + z_j^{NM} < Z^{Min}$ if and only if $d_{AA} < d_{AA}^{NM} \equiv \frac{d(15+52d)-1}{26+2d(39+8d)}$, where cutoff d_{AA}^{NM} satisfies $d_{AA}^{NM} < \widehat{d}_{AA} < d$ and increases in d.*

Figure 2 depicts aggregate abatement under no merger, Z^{NM}, which is unaffected by d_{AA}, and the minimal abatement that induces a merger, Z^{Min}, which is decreasing in d_{AA} as shown in Corollary 2. The figure assumes $c = 1/2$ and $d = 7$, which explains the upper bound on the horizontal axis since $d_{AA} < d$ by definition.[6]

Therefore, this equilibrium arises when aggregate abatement is relatively low, $Z^{NM} < Z^{Min}$, which holds when the EPA and AA are sufficiently asymmetric in their weight on pollution, $d_{AA} < d_{AA}^{NM}$, allowing for $d_{AA} = 0$ as a special case. Intuitively, when the AA assigns a low weight to pollution, it requires a large investment in abatement to approve the merger (i.e., cutoff Z^{Min} is high). This makes it unprofitable for any firm i to unilaterally deviate, increasing its individual abatement from z_i^{NM} to $Z^{Min} - z_j^{NM}$, so aggregate abatement meets Z^{Min}, inducing the merger.

An increase in pollution severity (higher d), leads to mergers becoming less likely in equilibrium. To understand this result, recall that cutoff Z^{Min} shifts upwards in d, as shown in Corollary 2 and, similarly, Z^{NM} shifts upwards in d, as shown in Proposition 1. The combined effect on cutoff d_{AA}^{NM} could, then, be ambiguous. But Proposition 1 shows that this cutoff moves rightward as d increases, which holds under all parameter conditions. This implies that the abatement threshold Z^{Min} rises more rapidly than firms' equilibrium investments Z^{NM}, making mergers less likely to be approved in equilibrium.

[6] In addition, Z^{Min} originates at $\frac{(1-c)(12d-1)}{14d}$ when $d_{AA} = 0$, which is unambiguously positive since $d \geq 1/2$ by definition, as depicted in the vertical intercept of figure 2. In this figure, where $c = 1/2$ and $d = 7$, the vertical intercept becomes 0.42; and the horizontal intercept is $\widehat{d}_{AA} = \frac{12d-1}{14} = \frac{83}{14} \simeq 5.93$.

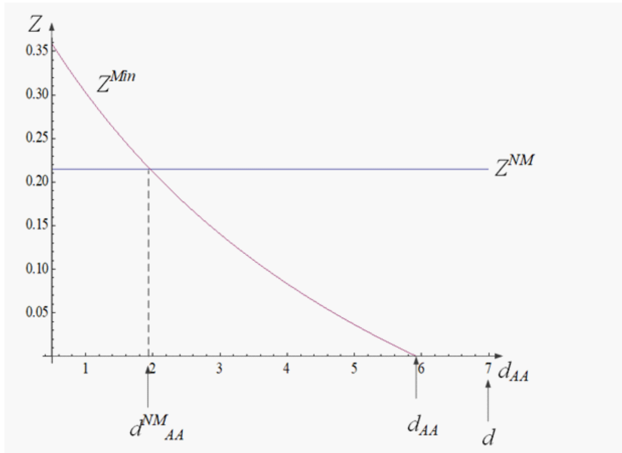

Figure 2. Cutoff d_{AA}^{NM}.

Merger. A similar argument applies in the case where the merger is approved, if $Z \geq Z^{Min}$ holds, where every firm i solves

$$\max_{z_i \geq 0} \ 2(q_i^M(t^M))^2 + t^M z_i - \frac{1}{2}(z_i)^2$$

since $\pi_i^M = 2(q_i^M)^2 + tz_i$, as shown in Lemma 1. Differentiating with respect to z_i, yields best response function

$$z_i^M(z_j) = \frac{(1-c)[2d(2d+1)-1]}{4d\,(3+4d)+1} - \frac{4d(1+d)}{4d\,(3+4d)+1} z_j \tag{2}$$

which is also decreasing in z_j, exhibiting similar comparative statics as $z_i^{NM}(z_j)$ (i.e., it is steeper as pollution becomes more severe). The next proposition finds investment in abatement in this context, z_i^M.

Proposition 2. *When $Z \geq Z^{Min}$ holds, equilibrium abatement is $z_i^M = \frac{(1-c)[2d(2d+1)-1]}{4d(4+5d)+1}$, which is positive for all admissible parameters, increasing in d but decreasing in c. In addition, $z_i^M + z_j^M \geq Z^{Min}$ if and only if $d_{AA} \geq d_{AA}^M \equiv \frac{d(26+64d)-1}{4d(23+4d)+38}$, where $d_{AA}^{NM} < d_{AA}^M < \widehat{d}_{AA} < d$, cutoff d_{AA}^M increases in d, and equilibrium abatement satisfies $z_i^M < z_i^{NM}$ for all admissible parameters.*

This equilibrium emerges when aggregate abatement is relatively high, which holds if government agencies are sufficiently symmetric in their weights on pollution, $d_{AA} \geq d_{AA}^M$. This condition becomes more stringent when d increases, making Proposition 2 more difficult to emerge.

Figure 3a superimposes the aggregate abatement under the merger, Z^M, on figure 2, where $Z^M < Z^{NM}$, along with cutoff d_{AA}^M. Figure 3b presents the same results, but depicting cutoffs d_{AA}^M, d_{AA}^{NM}, and $\widehat{d}_{AA}$ as a function of d on the horizontal axis and d_{AA} on the vertical axis. This representation helps identify the regions of (d, d_{AA})-pairs where agencies are relatively symmetric or asymmetric. Since cutoffs d_{AA}^{NM} and d_{AA}^{M} satisfy $d_{AA}^{NM} < d_{AA}^{M}$, as shown in Proposition 2, four regions arise, *a*-*d*, which we show in the Proposition 3 below.

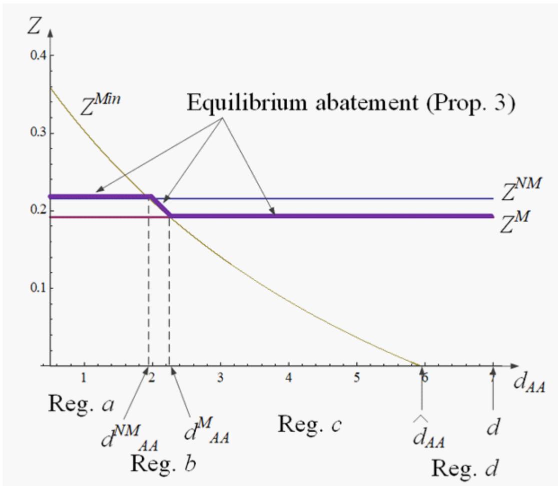

Fig. 3a. Investment regions - Role of Z^{Min}.

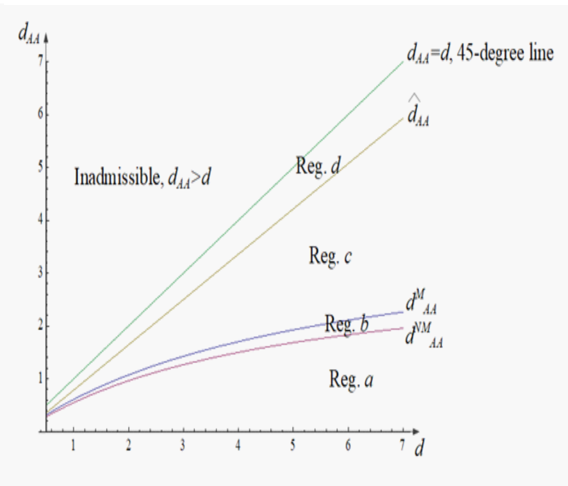

Fig. 3b. Investment regions - Asymmetries.

Proposition 3. *In equilibrium, investments in abatement satisfy:*

1. *Region a: If* $d_{AA} \leq d_{AA}^{NM}$*, every firm chooses* z_i^{NM}*, as found in Proposition 1, and a merger does not ensue.*

2. *Region b: If* $d_{AA}^{M} < d_{AA} \leq d_{AA}^{NM}$*, every firm chooses* $z_i^{Min} \equiv \frac{Z^{Min}}{2}$*, and a merger ensues.*

3. *Regions c and d: If* $d_{AA} > d_{AA}^{M}$*, every firm chooses* z_i^{M}*, as found in Proposition 2, and a merger ensues.*

When agencies are asymmetric, $d_{AA} \leq d_{AA}^{NM}$ in region a , firms cannot induce a merger approval regardless of their investment in abatement, and choose z_i^{NM}. While choosing the lower z_i^{M} is less costly, z_i^{NM} is optimal conditional on no merger, as shown in Proposition 1. In equilibrium, the EPA responds to z_i^{NM} by setting emission fee t^{NM} and firms, in turn, choose not to submit a merger request as they anticipate it being rejected.

In contrast, when agencies are relatively symmetric, $d_{AA} > d_{AA}^{M}$, firms can anticipate that both z_i^{M} and z_i^{NM} will lead to a merger approval.[7] In this case, the EPA sets emission fee t^{M}, implying that firms can save on abatement costs by investing in the lower z_i^{M}. In other words, conditional on merger, abatement z_i^{M} is profit maximizing, as shown in Proposition 2. Therefore, along the equilibrium path, firms first choose z_i^{M}, the EPA responds with fee t^{M}, firms then submit a merger request, and ultimately the AA approves the merger.

[7] In figure 3b, this occurs in region c, where $Z^{Min} > 0$, implying that the AA requires a positive investment in abatement to approve the merger, and in region d, where $Z^{Min} < 0$, entailing that the merger is approved regardless of the abatement level.

Finally, in region b, the AA assigns an intermediate weight to environmental damages relative to the EPA. In this context, firms can induce a merger investing z_i^{NM} or z_i^{Min}, but the latter is closer to the profit-maximizing abatement under a merger, z_i^M, since $z_i^{NM} > z_i^{Min} > z_i^M$, thus choosing z_i^{Min}.

Comparing this investment level against that in a setting where firms take a market structure as given, we find that abatement is higher than that under a merger, z_i^M, but lower than that under no merger, z_i^{NM}. Therefore, firms' ability to invest in abatement to affect the AA's decisions induces them to invest less than when their actions cannot change the market structure.

Overall, our results indicate that, if d_{AA} is relatively low, firms choose z_i^{NM} (region a); if d_{AA} is intermediate, they choose z_i^{Min} (region b); and otherwise they choose z_i^M (regions c and d), entailing that only one cutoff is relevant in terms of mergers, d_{AA}^{NM}. In other words, in countries where the AA assigns a low weight to pollution when evaluating mergers, firms anticipate most mergers being rejected, which leads them to invest more in abatement. However, in countries where merger guidelines account for environmental effects, such as the EU, may lead to more merger approvals, even when firms' investment in abatement is low, ultimately inducing firms to reduce their investments.

4 Merger profiles in other regulatory regimes

We next examine how our findings are affected by the coexistence of both regulatory agencies, by removing one agency at a time. In addition, we consider different time structures.

4.1 No antitrust authority

When the AA is absent, firms can merge without facing legal constraints. As shown in Lemma 3, firms find the merger unambiguously profitable. Anticipating an unrestricted merger, firms invest z_i^M in abatement during the first stage, as identified in Proposition 2, and the EPA responds with emission fee t^M. Comparing these results against those when the AA is present in the baseline model (see Proposition 3), we find that equilibrium behavior coincides across settings when government agencies exhibit symmetric weights on pollution, $d_{AA} \geq d_{AA}^M$. When agencies become more asymmetric, however, our findings indicate that firms invest *more* in abatement when the AA is present, investing z_i^{NM} or z_i^{Min} rather than z_i^M. In other words, firms invest more in abatement when such investments can influence merger outcomes than otherwise.

4.2 No environmental regulation

In the absence of environmental policy, the AA is more likely to approve the merger. To understand this result, let us apply backward induction in this setting. In the fourth stage, output decisions are unaffected, but in the third stage, the AA's merger approval criterion, $d_{AA} \geq \overline{d}_{AA}(t, Z)$, simplifies to $d_{AA} \geq \overline{d}_{AA}(0, Z) = \frac{5(1-c)}{2[7(1-c)-12Z]}$ since $t = 0$. Anticipating this merger approval cutoff, firms submit a merger request if and only if $d_{AA} \geq \overline{d}_{AA}(0, Z)$. In the first stage, however, firms have no incentives to invest in abatement for two reasons. First, abatement does not lower firms' tax burden, as in models with an exogenous market structure. Second, a larger abatement increases cutoff $\overline{d}_{AA}(0, Z)$, making it less likely for the AA to approve the merger. As shown in Lemma 2, this is because, when Z increases, the AA anticipates lower net emissions, making the pollution-reduction effect of the merger less necessary, leading this agency to block mergers under larger conditions. As a result, firms have stronger incentives to not invest in abatement when the EPA is absent, i.e., $z_i = 0$ and $Z = 0$.

Evaluating cutoff $\overline{d}_{AA}(0, Z)$ at $Z = 0$, yields $\overline{d}_{AA}(0, 0) = \frac{5}{14}$, indicating that, when environmental regulation is absent, the AA approves mergers under large parameter conditions, namely, values of d_{AA} that satisfy $d \geq d_{AA} > \frac{5}{14}$. Figure 4 superimposes cutoff $\overline{d}_{AA}(0, 0) = \frac{5}{14}$ into figure 3b, helping us compare merger profiles with and without environmental policy.

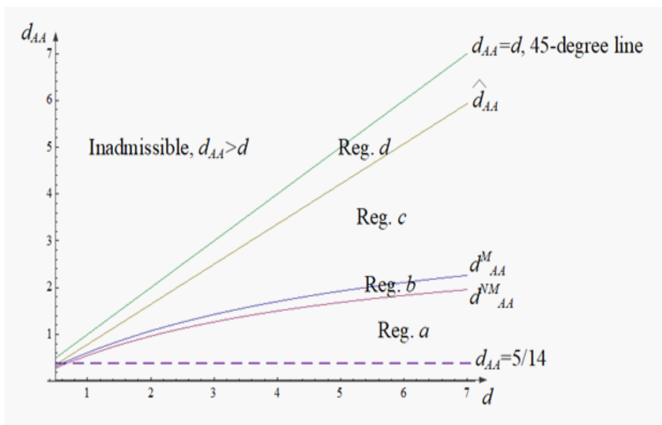

Figure 4. Mergers with and without EPA.

Relative to the setting with EPA, where the AA only approves mergers when agencies are relatively symmetric in their weights on pollution (regions b through d), the absence of environmental policy makes the AA more willing to approve mergers, i.e., for most pairs in region a. Intuitively, the AA observes that firms are not subject to emission fees and do not invest in abatement. In this context, the AA becomes more likely to approve mergers as an imperfect tool to reduce emissions.

4.3 Later investments

In this section, we still consider that both agencies are active, as in the main model, but allow for an alternative timing where investments in abatement happen *after* the merger has been evaluated by the AA. In this case, firms can no longer use investments as a tool to induce merger approvals, as we show next. By comparing merger profiles across different time structures, we seek to measure the strategic role in abatement decisions.

In particular, firms choose whether to submit a merger request in the first stage. In the second stage, the AA approves or blocks the merger; in the third stage, every firm chooses its investment in abatement, z_i; in the fourth stage, the EPA responds setting emission fee t; and, in the last stage, firms choose their output levels.

Stages 3-5. Solving the game by backward induction, the last three stages of the game are analogous to those in Poyago-Theotoky (2007). In particular, firms' output decisions in the last stage are unaffected (see Lemma 1). In the fourth stage, the EPA anticipates this output and responds with emission fee $t^{NM}(Z) = \frac{(4d-1)(1-c)-6dZ}{2(2d+1)}$ after no merger, and $t^{M}(Z) = \frac{(2d-1)(1-c)-4dZ}{2d+1}$ otherwise. As in Lemma 4, emission fees become more stringent as pollution is more severe (higher d), but less stringent as aggregate abatement increases (higher Z). In the third stage, every firm anticipates the emission fee pair $(t^{M}(Z), t^{NM}(Z))$, and invests z_i^M after observing that the merger was approved by the AA, as identified in Proposition 2, and z_i^{NM} when the merger does not ensue, as in Proposition 1, where $z_i^{NM} > z_i^M$.

Stages 1-2. While results in the last three stages are similar to those in our baseline model, the AA's decision rule in the second stage differs. In the baseline model, the AA decides whether to approve the merger after firms choose their investments in abatement, Z, approving the merger if $Z \geq Z^{Min}$. In the current setting, however, the AA can anticipate firms' investments in abatement in subsequent stages. Moreover, firms choose an abatement level in the baseline model, affecting their profits regardless of whether the AA responds by approving or blocking the merger; whereas in the current setting firms choose a different abatement level depending if a merger has been approved or not. In particular, the AA now approves the merger if welfare satisfies $W_{AA}^{M}(Z^{M}) \geq W_{AA}^{NM}(Z^{NM})$, where $Z^{M} = z_i^M + z_j^M$ and $Z^{NM} = z_i^{NM} + z_j^{NM}$.

This welfare ranking, however, never holds: the AA anticipates that, because the EPA responds to the AA's decision, emission fees induce the same aggregate output with and without the merger. Aggregate abatement is, nonetheless, larger under no merger, $Z^{NM} > Z^{M}$, leading to more profits and less net emissions. As a consequence, the AA blocks the merger request, which holds regardless of the weight that this agency assigns to environmental damages, d_{AA}. If $d_{AA} = 0$, the higher profits under no merger leads the AA to block it; and when $d_{AA} > 0$, the lower net emissions, $Z^{NM} > Z^{M}$, reinforce the incentive to block the merger. Finally, in the first stage, firms anticipate the AA declining all merger requests and do not submit one.

Comparison. Comparing these results with those in Proposition 3 and Corollary 3, we see that the AA's weight on pollution, d_{AA}, is inconsequential for merger decisions in the current setting. In other words, the AA anticipates the EPA addressing all externalities in subsequent stages, considering both abatement and output; whereas in the baseline model the AA responds to abatement decisions and emission fees, still having a chance to modify the market structure. Overall, later investments induce no mergers, as opposed to the baseline model where mergers can arise if agencies are relatively symmetric. However, under later investments firms invest more in abatement than when their investment decisions affect merger approvals.

4.4 Later emission fees

Consider now an alternative regulatory context where the emission fee is set *after* the AA has made its decision about approving or blocking the merger. In particular, firms choose abatement in the first stage, then they submit a merger request to the AA in the second stage, the AA responds approving or blocking the merger in the third stage, the EPA sets an emission fee t in the fourth stage, and finally firms respond with their output levels. Comparing this timing with that in the baseline model, where EPA has the ability to set fees before the AA evaluates merger requests, we can assess the role of emission fees at affecting merger approvals.

In the last stage, output decisions coincide with those in the baseline model (see Lemma 1). In the fourth stage, the EPA anticipates this output and sets emission fee $t^{NM}(Z) = \frac{(4d-1)(1-c)-6dZ}{2(2d+1)}$ after no merger and $t^{M}(Z) = \frac{(2d-1)(1-c)-4dZ}{2d+1}$ after merger; as in Lemma 4. As a consequence, the EPA's later role helps this agency induce the aggregate output regardless of the market structure, i.e., $Q^{NM}(t^{NM}) = Q^{M}(t^{M}) = \frac{1-c+2dZ}{2d+1}$.

Therefore, in the third stage, the AA anticipates the same output and welfare with and without the merger, $W^{M}(t^{M}(Z)) = W^{NM}(t^{NM}(Z))$, making this agency indifferent, thus approving the merger. In the second stage, firms anticipate this merger approval criterion and submit a merger request for all parameter values. Finally, in the first stage, firms invest Z^{M} in abatement, which holds for all values of d_{AA}. Therefore, firms invest less in abatement when the EPA acts later and mergers arise under all parameter conditions, yielding analogous results to those when the AA is absent (see section 4.1).

5 Extensions

5.1 Allowing for spillover effects and inefficiencies

We now extend our analysis by allowing for spillover effects, $\beta \in [0,1]$, and a general cost of abatement, $\gamma \geq 1$. Therefore, firm i's net emissions are $e_i = q_i - z_i - \beta z_j$, where $j \neq i$ and $\beta \in [0,1]$ denotes spillover effects; as in Poyago-Theotoky (2007) and Lambertini et al. (2017), among others. When $\beta = 0$, spillovers are absent; otherwise, every firm i benefits from its rivals' investment in abatement.

Appendix 1 identifies equilibrium behavior in each stage, showing how it is affected by β and γ. The appendix also finds investments under no merger, $z_i^{NM}(\beta,\gamma)$, and under mergers, $z_i^{M}(\beta,\gamma)$, showing that they coincide with those found in Propositions 1 and 2, respectively, when spillover effects are absent, $\beta = 0$, and $\gamma = 1$. We also identify under which conditions these investment levels are compatible with $Z < Z^{Min}$ and $Z \geq Z^{Min}$, respectively. For presentation purposes, we focus here on analyzing how mergers are affected by parameters β and γ.

As in previous sections, mergers do not arise when the AA assigns a sufficiently low weight to emissions, $d_{AA} < d_{AA}^{NM}(\beta,\gamma)$, where cutoff $d_{AA}^{NM}(\beta,\gamma)$ in this context becomes

$$d_{AA}^{NM}(\beta,\gamma) \equiv \frac{d(1+\beta)\left[5-3\beta+4d(7+3\beta)\right]+\gamma(1+2d)(12d-1)}{2(1+\beta)\left[6+d(25+8d+9\beta)\right]+14\gamma(1+2d)}.$$

Cutoff $d_{AA}^{NM}(\beta,\gamma)$ coincides with that in Proposition 1 when $\beta=0$ and $\gamma=1$, i.e., $d_{AA}^{NM}(0,1)=\frac{d(15+52d)-1}{26+2d(39+8d)}$, satisfies $\widehat{d}_{AA}>d_{AA}^{NM}(\beta,\gamma)$, and increases in γ for all parameter values. To understand this result, figure 5a depicts the relevant abatement levels that determine cutoff d_{AA}^{NM} in figure 3a, namely, Z^{Min} and Z^{NM}. The minimal aggregate abatement that induces the AA to approve the merger, Z^{Min}, is unaffected by an increase in γ. In contrast, the aggregate abatement under no merger, Z^{NM}, shifts downwards when abatement becomes more costly (higher γ), as shown in Appendix 1, and as depicted in figure 5a. As a consequence, the crossing point between Z^{NM} and Z^{Min}, moves rightward in figure 5a, increasing cutoff $d_{AA}^{NM}(\beta,\gamma)$. Intuitively, while inducing a merger is as difficult as in the baseline model, in terms of reaching Z^{Min}, its individual cost is now higher, implying that mergers arise under more restrictive conditions. Alternatively, the AA needs to care more about pollution for the merger to be approved.

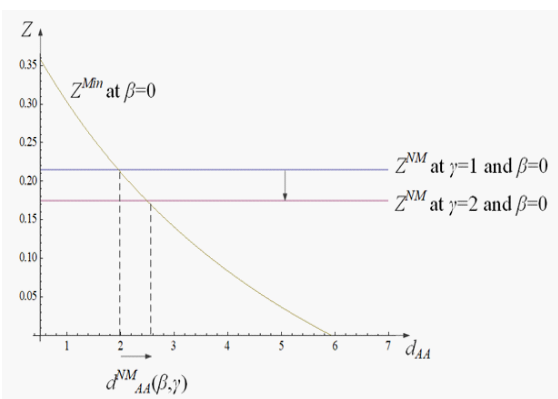

Fig. 5a. Role of γ.

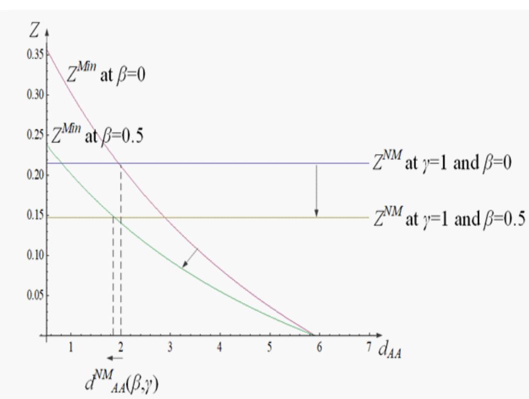

Fig. 5b. Role of β.

Figure 5b illustrates that an increase in spillover (higher β) gives rise to two effects. On one hand, it shifts Z^{Min} downwards since, as shown in Appendix 1, Z^{Min} decreases in β. On the other hand, higher spillovers also shift Z^{NM} downward.[8] The overall effect on cutoff $d_{AA}^{NM}(\beta,\gamma)$ depends, then, on which of the two effects dominates. In figure 5b, the former effect dominates, implying that $d_{AA}^{NM}(\beta,\gamma)$ shifts leftward. If, instead, the latter effect dominates, cutoff $d_{AA}^{NM}(\beta,\gamma)$ would shift rightward. In particular, this occurs if and only if $\gamma<\gamma^{NM}\equiv\frac{d(1+\beta)^2(4d-3)}{2d(3+4d+2\beta)-1}$.[9]

Figure 6 depicts cutoff γ^{NM} as a function of d on the horizontal axis, and evaluated at different values of β. The shaded region below γ^{NM} indicates (d,β)-pairs for which an increase in spillover

[8]Technically, Appendix 1 shows that Z^{NM} decreases in β if and only if $\gamma<\gamma_1$, where cutoff γ_1 originates at $\gamma_1=5.5$ when $d=1/2$ and $\beta=0$, and increases in both d and β, making condition $\gamma<\gamma_1$ less demanding. As a reference, when $d=1$ and $\beta=1/4$, this cutoff becomes $\gamma_1=16.05$, implying that condition $\gamma<\gamma_1$ holds for most parameter combinations.

[9]In the setting of figure 5b, where $d=7$, $\gamma=1$, and $\beta=0$, cutoff γ^{NM} becomes $\gamma^{NM}=\frac{175}{433}\simeq 0.40$. Since $\gamma=1>0.40=\gamma^{NM}$, cutoff $d_{AA}^{NM}(\beta,\gamma)$ shifts leftward, as shown in the figure.

effects induces a decrease in aggregate abatement Z^{NM} and, as a consequence, an increase in cutoff $d_{AA}^{NM}(\beta,\gamma)$, making mergers less likely to occur in equilibrium. Intuitively, the shaded region represents scenarios where emission fees are relatively stringent (high d) and abatement is inexpensive (low γ). When spillover effects become larger, cutoff γ^{NM} shifts upwards, expanding the shaded region, and making it more likely for free-riding effects to dominate, lowering Z^{NM} more intensively than Z^{Min} in figure 5b. In this context, cutoff $d_{AA}^{NM}(\beta,\gamma)$ is more likely to move rightward and hinder mergers in equilibrium.[10]

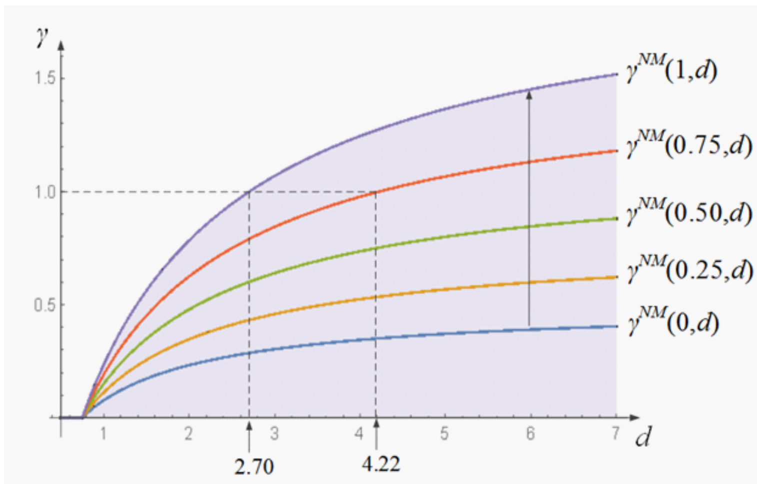

Figure 6. Free-riding incentives.

5.2 Allowing for environmental R&D cartels

A natural question is to what extent our above results change when firms coordinate their abatement decisions in an environmental R&D cartel (ERC), instead of each firm independently choosing its own abatement level. Equilibrium behavior in stages 2-5 are unaffected, but that in stage 1, where firms choose their abatement, changes since now they select z_i and z_j to maximize their joint profits. Appendix 2 identifies abatement levels in this context and their comparative statics, while here we focus on how our previous results are affected.

No mergers. Under no mergers, we show that $z_i^{NM,ERC} = \frac{(1-c)(8d^2+6d-1)}{2+8d(4+5d)}$, which exceeds its corresponding abatement without ERC, $z_i^{NM} = \frac{(1-c)[4d(2d+1)-1]}{2(18d^2+13d+1)}$ from Proposition 1, if and only if $d < \frac{5}{4}$. This is consistent with Proposition 1 in Poyago-Theotoky (2007), suggesting that firms have a tendency to overinvest when pollution is severe, i.e., $z_i^{NM,ERC} < z_i^{NM}$ if $d \geq \frac{5}{4}$, but $z_i^{NM,ERC} \geq z_i^{NM}$ otherwise.

In this context, the initial condition for no merger holds if $Z^{NM,ERC} = 2z_i^{NM,ERC} < Z^{Min}$,

[10] As an illustration, figure 6 depicts a dotted line at a fixed value of $\gamma = 1$, as in the baseline model. Cutoff γ^{NM} crosses through $\gamma = 1$ at $d = 4.22$ when $\beta = 3/4$, but decreases to $d = 2.70$ when spillovers increase to $\beta = 1$. Therefore, the values of d for which mergers are less likely to occur, in the shaded region, expand as spillover effects increase.

which entails $d_{AA} < d_{AA}^{NM,ERC} \equiv \frac{4d(3+16d)-1}{26+16d(6+d)}$. Cutoff $d_{AA}^{NM,ERC}$ exhibits similar properties as d_{AA}^{NM} in the baseline model, namely, it increases in d and lies below $\widehat{d}_{AA}$. Finally, comparing $d_{AA}^{NM,ERC}$ and d_{AA}^{NM} we obtain results that go in line with the above ranking in abatement efforts: when pollution is not severe, $d < \frac{5}{4}$, firms invest more in abatement under the ERC, and the AA is more likely to approve the merger since $d_{AA}^{NM} > d_{AA}^{NM,ERC}$. In contrast, when pollution becomes more severe, $d \geq \frac{5}{4}$, firms invest less in abatement under the ERC, and the AA is less likely to approve the merger because $d_{AA}^{NM} \leq d_{AA}^{NM,ERC}$.

Comparing the emission fee under no merger, $t^{NM}(Z)$ as found in Lemma 4, we find that the fee under the ERC is more stringent, $t^{NM}(Z^{NM,ERC}) > t^{NM}(Z^{NM})$, if and only if $d \geq \frac{5}{4}$. Therefore, when pollution is severe, firms invest less under the ERC, $z_i^{NM,ERC} \leq z_i^{NM}$, as shown above, and the EPA responds setting a more stringent fee.

Merger. Under a merger, we find that individual abatement becomes $z_i^{M,ERC} = \frac{(1-c)[4d(1+d)-1]}{20d(1+d)+1}$, which is unambiguously larger than that under no ERC, $z_i^M = \frac{(1-c)[2d(2d+1)-1]}{4d(4+5d)+1}$, identified in Proposition 2. Intuitively, firms internalize not only the external effects that abatement has on each other's profits, but also those from output decisions due the merger, letting them invest more in abatement for all parameters. In this setting, the initial condition for a merger to arise, $Z^{M,ERC} = 2z_i^{M,ERC} \geq Z^{Min}$, holds if and only if $d_{AA} \geq d_{AA}^{M,ERC} \equiv \frac{d(64d+22)-1}{2(8d^2+50d+19)}$. Cutoff $d_{AA}^{M,ERC}$ exhibits similar properties as d_{AA}^M and their comparison yields an unambiguous ranking in this case, $d_{AA}^M > d_{AA}^{M,ERC}$. In terms of figure 3a, since aggregate abatement is larger under the ERC, $Z^{M,ERC} > Z^M$, and cutoff Z^{Min} is unaffected by the ERC, the crossing point between $Z^{M,ERC}$ and Z^{Min} moves leftward, thus expanding the region where mergers are approved.

Comparing the emission fee under merger, $t^M(Z)$ as found in Lemma 4, we obtain that the emission fee with the ERC is less stringent, $t^M(Z^{M,ERC}) < t^M(Z^M)$, for all admissible parameter values. As shown above, firms invest more in abatement with than without the ERC under a merger, $Z^{M,ERC} > Z^M$, implying that the EPA responds setting a less stringent fee.

Combining our above results, we find that mergers are approved if and only if $d_{AA} > d_{AA}^{NM,ERC}$. Overall, this implies that the ERC facilitates merger approvals when pollution is not severe, $d < \frac{5}{4}$, with mergers arising even when regulatory agencies are not extremely asymmetric. Otherwise, the ERC hinders merger approvals.

5.3 Allowing for cost convexities

Consider now a more general cost function $C(q_i) = cq_i + \frac{h}{2}q_i^2$, where $c, h \geq 0$. Marginal costs are, then, $MC(q_i) = c + hq_i$, implying that, when $h = 0$, costs are linear, as in the baseline model; but when $h > 0$, costs become convex. This generalization reflects diseconomies of scale and allows us to assess how increasing marginal costs affect firms' strategic behavior and regulatory outcomes. Appendix 3 provides more technical details.

Starting in the last stage, we find that output becomes $q_i^{NM}(h) = \frac{1-c-t}{3+h}$ and $q_i^M(h) = \frac{1-c-t}{4+h}$, both being decreasing in h, as expected. Anticipating fewer emissions, the EPA sets a less stringent emission fee than under linear costs. In particular, the emission fee under no merger becomes

$t^{NM}(h) = t^{NM} - \frac{(4d-1)(1-c+2dZ)}{2(2d+1)[2(2d+1)+h]}h$, where t^{NM} is the emission fee under linear costs found in Lemma 4, implying that $t^{NM}(h) < t^{NM}$. A similar argument applies for the fee under mergers, $t^{M}(h) = t^{M} - \frac{(2d-1)(1-c+2dZ)}{(2d+1)[2(2d+1)+h]}h$, where t^{M} denotes the emission fee under linear costs.

The AA's merger approval condition also changes. Cutoff $d_{AA}(t, Z, h)$ increases in h, meaning that as costs become more convex, the output reduction from the merger becomes smaller, i.e., $\Delta q_i(h) \equiv q_i^{NM}(h) - q_i^{M}(h)$ decreases in h, implying that the AA requires a higher weight on environmental damages to approve a merger. In other words, the use of merger approvals as an imperfect tool to curb pollution becomes less necessary when costs are more convex.

In the first stage, firms' abatement decisions are also affected. Since cost convexities reduce the stringency of emission fees and the equilibrium profits with and without mergers, firms have less incentives to invest in abatement, i.e., $z_i^{NM}(h)$ and $z_i^{M}(h)$ are both decreasing in h.

Finally, we find the minimal aggregate abatement required for merger approval,

$$Z^{Min}(h) \equiv \frac{(1-c)\left[2+h-8d(3+h)+d_{AA}(28+8h)\right]}{2d(2h^2+11h+4d_{AA}+14)-4d_{AA}(2+h)(3+h)},$$

which coincides with that in Corollary 3 when costs are linear, $Z^{Min}(0) = Z^{Min}$, and exhibits similar comparative statics (increasing in d but decreasing in d_{AA}). An increase in cost convexities, however, produces a counterclockwise rotation in $Z^{Min}(h)$ with center at $d_{AA}^{ZMin}(h) \equiv \frac{d[76-8h(6+h)]-(2+h)^2}{92+16+8h(7+h)}$. That is, $Z^{Min}(h) < Z^{Min}(0)$ for all $d_{AA} < d_{AA}^{ZMin}(h)$, but $Z^{Min}(h) \geq Z^{Min}(0)$ otherwise; as depicted in figure 7.[11]

Intuitively, this shows that, when the AA assigns a relatively low weight to environmental damages, $d_{AA} < d_{AA}^{ZMin}(h)$, the merger leads to smaller output reductions, making the merger more attractive than under linear costs. Graphically, $Z^{Min}(h)$ decreases as h increases, facilitating merger approvals. In contrast, when the AA assigns a higher weight to environmental damages, $d_{AA} \geq d_{AA}^{ZMin}(h)$, the reduction in emissions from lower output is insufficient on its own to approve the merger. The AA thus requires higher levels of abatement to compensate, leading to an increase in the threshold $Z^{Min}(h)$.

[11] For consistency, the figure considers the same parameter values as figure 3a. It only depicts $Z^{NM}(h)$ and $Z^{Min}(h)$, since their crossing point determines the position of cutoff $d_{AA}^{NM}(h)$, which is the only threshold to determine the merger approval region.

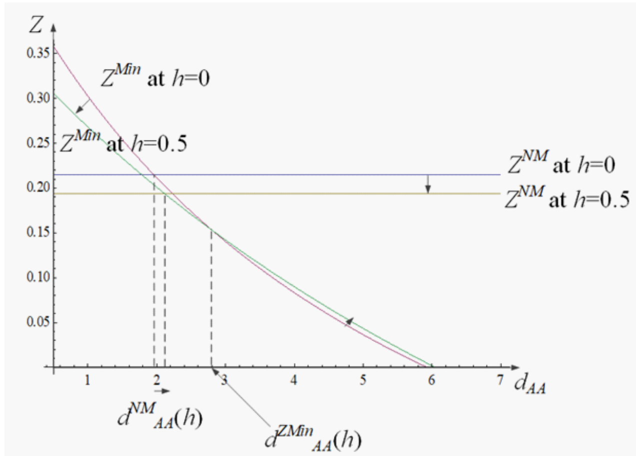

Figure 7. Cost convexities.

A final question is whether the crossing point between $Z^{NM}(h)$ and $Z^{Min}(h)$ increases or decreases in cost convexities, as captured by cutoff $d_{AA}^{NM}(h)$. On one hand, firms experience less incentives to invest in abatement, shifting $Z^{NM}(h)$ downwards, which should increase $d_{AA}^{NM}(h)$. On the other hand, $Z^{Min}(h)$ rotates counterclockwise, which should decrease $d_{AA}^{NM}(h)$. Appendix 3 shows that $d_{AA}^{NM}(h)$ unambiguously increases in h, as depicted in figure 7, implying that the former effect dominates. This means that, overall, the AA blocks the merger under a wider range of d_{AA} values when firms face diseconomies of scale than otherwise.

6 Discussion

Future mergers affecting investment. To assess how merger prospects shape firms' abatement decisions, we compare outcomes in two regulatory regimes: one in which the AA is active and one in which it is absent. When the AA is present, firms can strategically adjust their abatement levels to influence merger approvals. In contrast, when mergers proceed without regulatory oversight, firms have no incentive to alter their abatement. We find that when the AA and EPA are relatively asymmetric in their environmental valuation, both individual and aggregate abatement are higher with the AA than without it. However, when the agencies are closely aligned, abatement levels remain unchanged. Thus, the AA's presence tends to increase green investments and reduce net emissions, particularly when its environmental weights differ from those of the EPA. In this context, the AA anticipates a "tough" EPA and a stringent emission fee that will distort aggregate output downwards. To partially correct this inefficiency, the AA requires a high abatement level, which helps firms increase their output, making the merger more attractive for the AA.

At the same time, our findings raise caution regarding recent proposals to incorporate environmental considerations into merger guidelines, such as in the E.U., Australia, and Japan. When the AA assigns a small or moderate weight to environmental damages, its presence enhances abatement incentives—an outcome that is environmentally beneficial. However, if the AA exhibits similar environmental valuations as the EPA, the abatement threshold becomes non-binding, and firms' investment behavior remains unaffected. Our results also suggest that AAs could facilitate firms' abatement decisions by publicizing threshold Z^{Min} required for a merger to be approved.

Regulatory alignment. Our results reveal a non-monotonic relationship between regulatory alignment (the symmetry between agencies) and investment incentives. When the AA and EPA are either fully aligned or highly misaligned, the abatement threshold becomes trivially low or prohibitively high: firms either always or never meet it, and investment remains unchanged. However, when the AA assigns an intermediate weight to pollution, the threshold binds, and firms increase abatement to influence merger approval. This implies that moderate regulatory asymmetry can actually induce firms to strategically increase their investments in green technologies.

Timing of regulation. The timing of regulatory decisions significantly affects firms' strategic behavior. When abatement investments occur before merger review, firms can influence the AA's decision. If the AA acts first, however, this strategic channel disappears, as it anticipates lower post-merger abatement and blocks the merger regardless of its environmental weight. This underscores the importance of institutional sequencing: allowing firms to invest before review aligns private incentives with social goals, while reversing the order may undermine these effects. If, instead, emission fees occur after the AA decides whether to approve a merger, we find that firms invest less in abatement and all mergers are approved, as when the AA is absent.

Spillovers and ERCs. Our results are robust to spillovers and abatement costs. Spillovers can either support or hinder mergers, depending on whether they lower the approval threshold more than they reduce investment incentives. Similarly, higher abatement costs raise the threshold, hindering mergers. These findings suggest that policies reducing green technology costs or enhancing spillovers—such as R&D subsidies or innovation platforms—can indirectly make mergers more likely. Finally, ERCs facilitate merger approvals under larger parameter conditions (i.e., even when agencies are relatively asymmetric) if pollution is not severe. Otherwise, ERCs hinder merger approvals, requiring more symmetric agencies.

Further research. This model allows for several extensions. First, we can consider firms with asymmetric abatement efficiency. Second, we can allow for an industry with n firms, and k of them submitting a merger request. Third, one can allow for uncertainty—either in regulatory thresholds, emission fees, or environmental damages—potentially affecting firms' strategic abatement and merger approvals. Finally, one can empirically test the theoretical predictions using data on green investments and merger approvals across different countries.

7 Appendix

7.1 Appendix 1 - Allowing for abatement costs and spillovers

Fifth stage, output. Output levels coincide with those in Lemma 1, $q_i^{NM} = \frac{1-c-t}{3}$ under no merger and $q_i^M = \frac{1-c-t}{4}$ under a merger; but profits are now $(1-q_i-q_j)q_i - cq_i - t(q_i - z_i - \beta z_j)$, becoming $\pi_i^{NM} = (q_i^{NM})^2 + t(z_i + \beta z_j)$ after no merger and $\pi_i^M = (q_i^M)^2 + t(z_i + \beta z_j)$ after a merger.

Fourth stage, AA decision. The AA anticipates output levels in the next stage and approves a merger if it is welfare improving, $W_{AA}^M \geq W_{AA}^{NM}$, which holds if and only if $d_{AA} \geq \overline{d}_{AA}(t, Z) \equiv \frac{5(1-c)+7t}{2[7(1-c-t)-12(1+\beta)Z]}$. Cutoff $\overline{d}_{AA}(t, Z) > 0$ since $Z < \frac{1-c}{2}$ by definition, coincides with that in Lemma 2 when spillovers are absent, $\beta = 0$. In addition, $\overline{d}_{AA}(t, Z)$ satisfies $\frac{\partial \overline{d}_{AA}(t,Z)}{\partial t} = \frac{42[1-c+(1+\beta)Z]}{[7(1-c-t)-12(1+\beta)Z]^2}$, which is positive since $Z < \frac{1-c}{2(1+\beta)}$ holds by definition; $\frac{\partial \overline{d}_{AA}(t,Z)}{\partial Z} = \frac{6(1+\beta)[5(1-c)+7t]}{[7(1-c-t)-12(1+\beta)Z]^2} > 0$, $\frac{\partial \overline{d}_{AA}(t,Z)}{\partial \beta} = \frac{6[5(1-c)+7t]Z}{[7(1-c-t)-12(1+\beta)Z]^2} > 0$, and $\frac{\partial \overline{d}_{AA}(t,Z)}{\partial c} = \frac{42t+30(1+\beta)Z}{[7(1-c-t)-12(1+\beta)Z]^2} > 0$.

Third stage, merger submission. Anticipating the AA's decision, the merging entity submits a merger request if and only if $d_{AA} \geq \overline{d}_{AA}(t, Z)$, because its profit gain from the merger is $\left(\pi_i^M + \pi_j^M\right) - \left(\pi_i^{NM} + \pi_j^{NM}\right) = \frac{(1-c-t)^2}{36}$, which is unambiguously positive. Then, our results in this stage coincide with those in Lemma 4.

Second stage, emission fee. If $d_{AA} \geq \overline{d}_{AA}(t, Z)$ holds, the EPA anticipates a merger will ensue, choosing the emission fee t that solves

$$\begin{aligned} \max_{t \geq 0} \; W^M \;=\; & \frac{1}{2}\left(\frac{1-c-t}{4}\right)^2 + 2\left(\frac{1-c-t}{4}\right)^2 + tZ(1+\beta) - \frac{\gamma}{2}Z^2 \\ & + t\left(\frac{2\left(1-c-t\right)}{4}\right) - d\left[\frac{2\left(1-c-t\right)}{4} - (1+\beta)Z\right]^2 \end{aligned}$$

Differentiating with respect to t, and solving for t, yields a fee $t^M = \frac{(2d-1)(1-c)-4dZ(1+\beta)}{2d+1}$, which is positive for all $d > d^M \equiv \frac{1-c}{2[1-c+2Z(1+\beta)]}$, where cutoff d^M is positive since $Z < \frac{1-c}{2}$ by definition. In addition, fee t^M satisfies $\frac{\partial t^M}{\partial d} = \frac{4[1-c-Z(1+\beta)]}{(2d+1)^2} > 0$ since $Z < \frac{1-c}{2}$ by assumption; $\frac{\partial t^M}{\partial Z} = -\frac{4d(1+\beta)}{2d+1} < 0$; $\frac{\partial t^M}{\partial \beta} = -\frac{4dZ}{2d+1} < 0$; and $\frac{\partial t^M}{\partial c} = -\frac{2d-1}{2d+1} < 0$ since $d \geq 1/2$ by definition.

If, instead, $d_{AA} < \overline{d}_{AA}(t, Z)$ holds, the EPA anticipates that a merger will not ensue in subsequent stages, and chooses t to solve

$$\begin{aligned} W^{NM} \;=\; & \frac{1}{2}\left(\frac{1-c-t}{3}\right)^2 + 2\left(\frac{1-c-t}{3}\right)^2 + tZ(1+\beta) - \frac{\gamma}{2}Z^2 \\ & + t\left(\frac{2(1-c-t)}{3}\right) - d\left[\frac{2(1-c-t)}{3} - (1+\beta)Z\right]^2 \end{aligned}$$

Differentiating with respect to t, and solving for t, yields a fee $t^{NM} = \frac{(4d-1)(1-c)-6dZ(1+\beta)}{2(2d+1)}$, which is positive for all $d > d^{NM} \equiv \frac{1-c}{2[2(1-c)-3Z(1+\beta)]}$, where cutoff d^{NM} is positive since $Z < \frac{1-c}{2}$

by definition. In addition, the fee differential is $t^{NM} - t^{M} = \frac{1-c+2dZ(1+\beta)}{2(2d+1)}$, being unambiguously positive, implying that $t^{NM} > t^{M}$, and with this fee differential increasing as spillover effects become larger. Furthermore, fee t^{NM} satisfies $\frac{\partial t^{NM}}{\partial d} = \frac{3[1-c-Z(1+\beta)]}{(2d+1)^2} > 0$ since $Z < \frac{1-c}{2}$ by assumption; $\frac{\partial t^{NM}}{\partial Z} = -\frac{3d(1+\beta)}{2d+1} < 0$; $\frac{\partial t^{NM}}{\partial \beta} = -\frac{3dZ}{2d+1} < 0$; and $\frac{\partial t^{M}}{\partial c} = -\frac{4d-1}{2(2d+1)} < 0$ since $d \geq 1/2$ by definition.

Evaluating cutoff $d_{AA}(t, Z)$ at fee t^{M}, we obtain $d_{AA}(t^{M}, Z) = \frac{(1-c)(12d-1)-14dZ(1+\beta)}{14(1-c)-4Z(1+\beta)(3-d)}$, where the numerator is positive if $(1-c) > \frac{14d}{12d-1}Z(1+\beta)$, which holds since $Z < \frac{1-c}{2}$ by definition, and $\frac{14d}{12d-1} < 2$ for all admissible values of d. Similarly, the denominator of $d_{AA}(t^{M}, Z)$ is positive if $(1-c) > \frac{4(3-d)}{14}Z(1+\beta)$, which holds since $Z < \frac{1-c}{2}$ by definition, and $\frac{4(3-d)}{14} < 2$ for all admissible values of d.

In addition, cutoff $d_{AA}(t^{M}, Z)$ exhibits the same properties as in Corollary 1 of the baseline model: (i) it is lower than d since $d - d_{AA}(t^{M}, Z) = \frac{(2d+1)[1-c+2dZ(1+\beta)]}{14(1-c)-4Z(1+\beta)(3-d)} > 0$; (ii) originates at $d_{AA}(t^{M}, 0) = \frac{12d-1}{14}$ when $Z = 0$; (iii) satisfies $\frac{\partial d_{AA}(t^{M},Z)}{\partial Z} = -\frac{3(1-c)(1+\beta)(2d+1)^2}{[7(1-c)-2Z(1+\beta)(3-d)]^2} < 0$, $\frac{\partial d_{AA}(t^{M},Z)}{\partial d} = \frac{42[1-c-(1+\beta)Z]^2}{[7(1-c)-2Z(1+\beta)(3-d)]^2} > 0$, $\frac{\partial d_{AA}(t^{M},Z)}{\partial c} = -\frac{3Z(1+\beta)(2d+1)^2}{[7(1-c)-2Z(1+\beta)(3-d)]^2} < 0$, and $\frac{\partial d_{AA}(t^{M},Z)}{\partial \beta} = -\frac{3(1-c)(2d+1)^2}{[7(1-c)-2Z(1+\beta)(3-d)]^2} < 0$.

Finally, setting $d_{AA} \geq \overline{d}_{AA}(t, Z)$ and solving for Z, we find $Z \leq Z^{Min} \equiv \frac{(1-c)(12d-14d_{AA}-1)}{2(1+\beta)[7d+2d_{AA}(d-3)]}$. Cutoff Z^{Min} coincides with that in Corollary 2 when spillover effects are absent, $\beta = 0$, but otherwise shifts downwards since $\frac{\partial Z^{Min}}{\partial \beta} = -\frac{(1-c)(12d-14d_{AA}-1)}{2(1+\beta)^2[7d+2d_{AA}(d-3)]} < 0$ for all $d_{AA} < \widehat{d}_{AA}$.

First stage, no merger. In the first stage, if $Z < Z^{Min}$ holds, every firm i anticipates the EPA setting emission fee t^{NM}, and solves

$$\max_{z_i \geq 0} \ (q_i^{NM}(t^{NM}))^2 + t^{NM}(z_i + \beta z_j) - \frac{\gamma}{2}(z_i)^2$$

which is evaluated at fee t^{NM}. Differentiating with respect to z_i, solving for z_i, yields best response function

$$\begin{aligned} z_i^{NM}(z_j) \quad &= \quad \frac{(1-c)[2d(2+\beta+4d)-1]}{4d(1+\beta)[3+d(5-\beta)]+2\gamma(2d+1)^2} \\ &\quad - \frac{d(1+\beta)^2(3+4d)}{2d(1+\beta)[3+d(5-\beta)]+\gamma(2d+1)^2} z_j \end{aligned}$$

Invoking symmetry, $z_i = z_j$, yields an equilibrium abatement of

$$z_i^{NM}(\beta, \gamma) = \frac{(1-c)[2d(2+\beta+4d)-1]}{2d(1+\beta)[3(3+\beta)+2d(7+\beta)]+2\gamma(2d+1)^2},$$

which is unambiguously positive and coincides with that in Proposition 1 when $\beta = 0$ and $\gamma = 1$, i.e., $z_i^{NM}(0, 1) = \frac{(1-c)[4d(2d+1)-1]}{2(18d^2+13d+1)}$. Equilibrium abatement is decreasing in γ since $\frac{\partial z_i^{NM}(\beta,\gamma)}{\partial \gamma} =$

$-\frac{(1-c)(1+2d)^2[2d(2+\beta+4d)-1]}{[2d(1+\beta)[3(3+\beta)+2d(7+\beta)]+\gamma[4d(1+d)+1]]^2} < 0$, and decreasing in β if

$$\frac{\partial z_i^{NM}(\beta,\gamma)}{\partial \beta} = -\frac{(1-c)d(1+2d)^2\left[dA-\gamma-3(2+\beta)\right]}{\left[d(1+\beta)[3(3+\beta)+2d(7+\beta)]+\gamma\left[4d(1+d)+1\right]\right]^2} < 0,$$

where $A \equiv 7+16d^2(4+\beta)+\beta(10+3\beta)+2d(33+\beta(16+\beta)-2\gamma)-4\gamma$. Condition $\frac{\partial z_i^{NM}(\beta,\gamma)}{\partial \beta} < 0$ holds if and only if

$$\gamma < \gamma_1 \equiv \frac{16d^3(4+\beta)+2d^2[33+\beta(16+\beta)]+d(1+\beta)(7+3\beta)-3(2+\beta)}{(1+2d)^2}.$$

Cutoff γ_1 increases in d and shifts upwards in β for all admissible parameters. Therefore, γ_1 reaches its lowest height at $d = 1/2$ and $\beta = 0$, where $\gamma_1 = \frac{11}{2} = 5.5$, while increases in d, β, or both, making condition $\gamma < \gamma_1$ less demanding.

Evaluating aggregate abatement, $Z^{NM}(\beta,\gamma) = z_i^{NM}(\beta,\gamma) + z_j^{NM}(\beta,\gamma)$, we obtain that it is compatible with the initial condition $Z < Z^{Min}$ if $Z^{NM}(\beta,\gamma) < Z^{Min}$, which holds if and only if

$$d_{AA} < d_{AA}^{NM}(\beta,\gamma) \equiv \frac{d(1+\beta)\left[5-3\beta+4d(7+3\beta)\right]+\gamma(1+2d)(12d-1)}{2(1+\beta)\left[6+d(25+8d+9\beta)\right]+14\gamma(1+2d)}.$$

Cutoff $d_{AA}^{NM}(\beta,\gamma)$ coincides with that in Proposition 1 when $\beta = 0$ and $\gamma = 1$, i.e., $d_{AA}^{NM}(0,1) = \frac{d(15+52d)-1}{26+2d(39+8d)}$, satisfies $\widehat{d}_{AA} > d_{AA}^{NM}(\beta,\gamma)$ since their difference is

$$\widehat{d}_{AA} - d_{AA}^{NM}(\beta,\gamma) = \frac{3(1+2d)(1+\beta)\left[2d(2+4d+\beta)-1\right]}{7(1+\beta)\left[6+d(25+8d+9\beta)\right]+49\gamma(1+2d)} > 0.$$

In addition, cutoff $d_{AA}^{NM}(\beta,\gamma)$ increases in γ because $\frac{\partial d_{AA}^{NM}(\beta,\gamma)}{\partial \gamma} = \frac{3(1+2d)^2(1+\beta)[2d(4d+2+\beta)-1]}{\left[(1+\beta)[6+d(25+8d+9\beta)]+7\gamma(1+2d)\right]^2} > 0$, and increases in β if and only if $\frac{\partial d_{AA}^{NM}(\beta,\gamma)}{\partial \beta} = \frac{3(1+2d)^2\left[d(1+\beta)^2(4d-3)+\gamma-2d\gamma(3+4d+2\beta)\right]}{\left[(1+\beta)[6+d(25+8d+9\beta)]+7\gamma(1+2d)\right]^2} > 0$, which holds when $\gamma < \gamma^{NM} \equiv \frac{d(1+\beta)^2(4d-3)}{2d(3+4d+2\beta)-1}$. Cutoff γ^{NM} is positive for all admissible parameter values, increases in d since $\frac{\partial \gamma^{NM}}{\partial d} = \frac{(1+\beta)^2[3+8d(2d(3+\beta)-1)]}{\left[2d(3+4d+2\beta)-1\right]^2} > 0$ since $d \geq 1/2$ by definition, and increases in β because $\frac{\partial \gamma^{NM}}{\partial \beta} = \frac{2d(1+\beta)(4d-3)[2d(4d+2+\beta)-1)]}{\left[2d(3+4d+2\beta)-1\right]^2} > 0$ since $d \geq 1/2$ by assumption.

First stage, merger. If, instead, $Z \geq Z^{Min}$ holds, every firm i solves

$$\max_{z_i \geq 0} \; 2(q_i^M(t^M))^2 + t^M(z_i+\beta z_j) - \frac{\gamma}{2}(z_i)^2.$$

Differentiating with respect to z_i, , and solving for z_i, yields best response function

$$z_i^M(z_j) = \frac{(1-c)[2d(1+2d+\beta)-1]}{4d(1+\beta)[2+d(\beta-3)]-\gamma(1+2d)^2} - \frac{4d(1+\beta)^2(1+d)}{4d(1+\beta)[2+d(\beta-3)]-\gamma(1+2d)^2} z_j$$

Invoking symmetry, $z_i = z_j$, yields an equilibrium abatement of

$$z_i^M(\beta,\gamma) = \frac{(1-c)[2d(1+2d+\beta)-1]}{4d[3+\beta(4+\beta)+\gamma+d(4+4\beta+\gamma)+\gamma]+\gamma},$$

which is unambiguously positive since $d \geq 1/2$ by definition, and coincides with that in Proposition 2 when $\beta = 0$ and $\gamma = 1$, i.e., $z_i^M(0,1) = \frac{(1-c)[2d(2d+1)-1]}{4d(4+5d)+1}$. Equilibrium abatement is decreasing in γ since $\frac{\partial z_i^M(\beta,\gamma)}{\partial\gamma} = -\frac{(1-c)(1+2d)^2[2d(1+2d+\beta)-1]}{[4d[3+\beta(4+\beta)+\gamma+d(4+4\beta+\gamma)+\gamma]+\gamma]^2} < 0$, and decreasing in β if

$$\frac{\partial z_i^M(\beta,\gamma)}{\partial\beta} = -\frac{2(1-c)d\left[4d\left[8d^2+\beta(2+\beta)+d(8+4\beta-\gamma)-\gamma-1\right]-8-4\beta-\gamma\right]}{[4d[3+\beta(4+\beta)+\gamma+d(4+4\beta+\gamma)+\gamma]+\gamma]^2} < 0,$$

which holds if and only if $\gamma < \gamma_2 \equiv \frac{4d\left[\beta(2+\beta)+8d^2+4d(2+\beta)-1\right]-4(2+\beta)}{(1+2d)^2}$. Cutoff γ_2 increases in d and shifts upwards in β for all admissible parameters. Therefore, γ_2 reaches its lowest height at $d = 1/2$ and $\beta = 0$, where $\gamma_2 = \frac{1}{2}$, and then increases in d, β, or both, making condition $\gamma < \gamma_2$ less demanding.

Evaluating aggregate abatement, $Z^M(\beta,\gamma) = z_i^M(\beta,\gamma) + z_j^M(\beta,\gamma)$, we obtain that it is compatible with the initial condition $Z \geq Z^{Min}$ if $Z^M(\beta,\gamma) \geq Z^{Min}$, which holds if and only if

$$d_{AA} \geq d_{AA}^M(\beta,\gamma) \equiv \frac{4d(1+\beta)(4+10d-\beta)+\gamma\left[2d(5+12d)-1\right]}{8(1+\beta)\left[3+d(8+2d+\beta)\right]+14\gamma(1+2d)}.$$

Cutoff $d_{AA}^M(\beta,\gamma)$ coincides with that in Proposition 2 when $\beta = 0$ and $\gamma = 1$, i.e., $d_{AA}^M(0,1) = \frac{d(26+64d)-1}{4d(23+4d)+38}$, satisfies $\widehat{d}_{AA} > d_{AA}^M(\beta,\gamma) > d_{AA}^{NM}(\beta,\gamma)$ for all admissible parameters, increases in γ because $\frac{\partial d_{AA}^M(\beta,\gamma)}{\partial\gamma} = \frac{6(1+2d)^4(1+\beta)[2d(1+2d+\beta)-1]}{[12(1+\beta)+4d(1+\beta)(8+2d+\beta)+7\gamma(1+2d)]^2} > 0$, and increases in β if and only if $\frac{\partial d_{AA}^M(\beta,\gamma)}{\partial\beta} = \frac{6(1+2d)^4\left[\gamma-4d\left[(1+\beta)^2+\gamma(1+d+\beta)\right]\right]}{[12(1+\beta)+4d(1+\beta)(8+2d+\beta)+7\gamma(1+2d)]^2} > 0$, which holds when $\gamma < \gamma^M \equiv -\frac{4d(1+\beta)^2}{4d(1+d+\beta)-1}$. Cutoff γ^M is unambiguously negative since $d \geq 1/2$ by definition, implying that condition $\gamma < \gamma^M$ cannot hold, and that cutoff $d_{AA}^M(\beta,\gamma)$ is decreasing in β for all parameter values.

7.2 Appendix 2 - Allowing for ERCs

No merger. In the first stage, if $Z < Z^{Min}$ holds, firms anticipate the EPA setting emission fee t^{NM}. Maximizing their joint profits, they coordinate z_i and z_j to solve

$$\max_{z_i,z_j\geq 0} \left[(q_i^{NM}(t^{NM}))^2 + t^{NM}z_i - \frac{1}{2}(z_i)^2\right] + \left[(q_j^{NM}(t^{NM}))^2 + t^{NM}z_j - \frac{1}{2}(z_j)^2\right]$$

which yields $z_i^{NM,ERC} = z_j^{NM,ERC} = \frac{(1-c)(8d^2+6d-1)}{2+8d(4+5d)}$, which is positive since $d \geq 1/2$ by definition. Comparing individual abatement with and without the ERC, yields

$$z_i^{NM,ERC} - z_i^{NM} = \frac{(1-c)d(1+2d)^2(5-4d)}{2(18d^2+13d+1)(20d^2+16d+1)},$$

which is positive for all $d < \frac{5}{4}$, but negative otherwise. Therefore, when pollution is not severe, $d < \frac{5}{4}$, firms invest more in abatement under the ERC than when each firm independently chooses its own abatement level, $z_i^{NM,ERC} > z_i^{NM}$; but when pollution is sufficiently severe, $d \geq \frac{5}{4}$, they invest less intensively, $z_i^{NM,ERC} \leq z_i^{NM}$.

Aggregate abatement in this setting is, then, $Z^{NM,ERC} = 2z_i^{NM,ERC}$. Comparing $Z^{NM,ERC}$ and the cutoff Z^{Min}, we find that the initial condition holds if $Z^{NM,ERC} < Z^{Min}$, which entails $d_{AA} < d_{AA}^{NM,ERC} \equiv \frac{4d(3+16d)-1}{26+16d(6+d)}$. Cutoff $d_{AA}^{NM,ERC}$ originates at $d_{AA} = 0.26$ when $d = 1/2$, is unambiguously positive since $d \geq 1/2$ by definition, increases in d because $\frac{\partial d_{AA}^{NM,ERC}}{\partial d} = \frac{6[17+4d(35+62d)]}{[13+8d(6+d)]^2} > 0$, and lies below cutoff $\widehat{d}_{AA}$ since $\widehat{d}_{AA} - d_{AA}^{NM,ERC} = \frac{3(1+2d)(8d^2+6d-1)}{7[13+8d(6+d)]} > 0$.

Comparing cutoff $d_{AA}^{NM,ERC}$ against its counterpart in the baseline model (identified in Proposition 1), we obtain that their difference is $d_{AA}^{NM} - d_{AA}^{NM,ERC} = \frac{3d(1+2d)^2(5-4d)}{[13+8d(6+d)][13+d(39+8d)]}$, which is positive for all $d < \frac{5}{4}$. Hence, when pollution is not severe, $d < \frac{5}{4}$, firms invest more in abatement under the ERC, as shown above, and the AA is more likely to approve the merger since $d_{AA}^{NM} > d_{AA}^{NM,ERC}$. In contrast, when pollution becomes more severe, $d \geq \frac{5}{4}$, firms invest less in abatement under the ERC, and the AA is less likely to approve the merger because $d_{AA}^{NM} \leq d_{AA}^{NM,ERC}$.

Emission fees. Comparing the emission fee under no merger, $t^{NM}(Z) = \frac{(4d-1)(1-c)-6dZ}{2(2d+1)}$ as found in Lemma 4, evaluated at the aggregate abatement with and without ERC, $Z^{NM,ERC}$ and Z^{NM}, we find that $t^{NM}(Z^{NM,ERC}) = \frac{(1-c)[4d(4d-1)-1]}{2+8d(4+5d)} > 0$ and $t^{NM}(Z^{NM}) = \frac{(1-c)(3d-1)(4d+1)}{2(18d^2+13d+1)}$ since $d \geq 1/2$ by definition, and their difference is $t^{NM}(Z^{NM,ERC}) - t^{NM}(Z^{NM}) = \frac{3d^2(1-c)(8d^2+6d-1)}{2(18d^2+13d+1)}$, which is positive if and only if $d \geq \frac{5}{4}$. Therefore, when pollution is severe, firms invest less under the ERC, $z_i^{NM,ERC} \leq z_i^{NM}$, and the EPA responds setting a more stringent fee.

Merger. In the first stage, if $Z \geq Z^{Min}$ holds, firms anticipate the EPA setting emission fee t^M. Maximizing their joint profits, they coordinate z_i and z_j to solve

$$\max_{z_i, z_j \geq 0} \left[2(q_i^M(t^M))^2 + t^M z_i - \frac{1}{2}(z_i)^2\right] + \left[2(q_j^M(t^M))^2 + t^M z_j - \frac{1}{2}(z_j)^2\right]$$

which yields $z_i^{M,ERC} = z_j^{M,ERC} = \frac{(1-c)[4d(1+d)-1]}{20d(1+d)+1}$, which is positive since $d \geq 1/2$ by definition. Comparing individual abatement with and without the ERC, yields

$$z_i^{M,ERC} - z_i^M = \frac{6d(1-c)(1+2d)^2}{[20d(1+d)+1]\,[4d(4+5d)+1]},$$

which is unambiguously positive, entailing that $z_i^{M,ERC} > z_i^M$ holds for all admissible parameters. In this context, aggregate abatement is $Z^{M,ERC} = 2z_i^{M,ERC}$. Comparing $Z^{M,ERC}$ and cutoff Z^{Min}, we find that the initial condition holds if $Z^{M,ERC} \geq Z^{Min}$, which entails $d_{AA} \geq d_{AA}^{M,ERC} \equiv \frac{d(64d+22)-1}{2(8d^2+50d+19)}$. Cutoff $d_{AA}^{M,ERC}$ originates at $d_{AA} = 0.28$ when $d = 1/2$, is unambiguously positive since $d \geq 1/2$ by definition, increases in d because $\frac{\partial d_{AA}^{M,ERC}}{\partial d} = \frac{18[84d^2+68d+13]}{(8d^2+50d+19)^2} > 0$, and lies below cutoff $\widehat{d}_{AA}$ since $\widehat{d}_{AA} - d_{AA}^{M,ERC} = \frac{6(1+2d)[4d(1+d)-1]}{7(8d^2+50d+19)} > 0$.

Comparing cutoff $d_{AA}^{M,ERC}$ against its counterpart in the baseline model (identified in Proposition 2), we obtain that their difference is $d_{AA}^{M} - d_{AA}^{M,ERC} = \frac{36d(1+2d)^2}{(8d^2+58d+19)(8d^2+50d+19)}$, which is unambiguously positive, entailing that $d_{AA}^{M} > d_{AA}^{M,ERC}$ under all admissible parameters.

Emission fees. Comparing the emission fee under merger, $t^M(Z) = \frac{(2d-1)(1-c)-4dZ}{2d+1}$ as found in Lemma 4, evaluated at the aggregate abatement with and without ERC, $Z^{M,ERC}$ and Z^M, we find that $t^M(Z^{M,ERC}) = \frac{(1-c)[4d(d-2)-1]}{20d(1+d)+1}$, which is positive for all $d > \frac{2+\sqrt{5}}{2} \simeq 2.11$; $t^M(Z^M) = \frac{(1-c)[4d(d-1)-1]}{4d(4+5d)+1}$, which is positive for all $d > \frac{1+\sqrt{2}}{2} \simeq 1.21$; and their difference is $t^M(Z^{M,ERC}) - t^M(Z^M) = -\frac{48d^2(1-c)(1+2d)}{[20d(1+d)+1][4d(4+5d)+1]}$, which is unambiguously negative, implying that $t^M(Z^{M,ERC}) < t^M(Z^M)$ for all admissible parameters. As shown above, firms invest more in abatement with than without the ERC under a merger, $z_i^{M,ERC} > z_i^M$, implying that the EPA responds setting a less stringent fee.

Finally, to measure the length of region b, we find the difference between cutoffs $d_{AA}^{M,ERC}$ and $d_{AA}^{NM,ERC}$, which yields $d_{AA}^{M,ERC} - d_{AA}^{NM,ERC} = \frac{3+6d(5+6d-4d^2)}{[13+8d(6+d][57+2d(83+12d)]}$, which is positive for all $d < \frac{3+\sqrt{29}}{4} \simeq 2.09$.

7.3 Appendix 3 - Allowing for cost convexities

Fifth stage, output. Under no merger, every firm i independently chooses its output q_i to solve

$$\max_{q_i \geq 0} \ \pi_i = (1 - q_i - q_j)q_i - \left(cq_i + \frac{h}{2}q_i^2\right) - t(q_i - z_i)$$

Differentiating with respect to q_i, yields best response function $q_i(q_j) = \frac{1-c-t}{2+h} - \frac{1}{2+h}q_j$. Firm j's best response function is analogous. In a symmetric equilibrium, $q_i = q_j = q_i^{NM}$, we obtain that $q_i^{NM} = \frac{1-c-t}{2+h} - \frac{1}{2+h}q_i^{NM}$. Solving for q_i^{NM}, yields $q_i^{NM}(h) = \frac{1-c-t}{3+h}$. Individual output coincides with that in Lemma 2 when costs are linear, $h = 0$, but otherwise decreases in h. Aggregate output in this setting becomes $Q^{NM}(h) = 2q_i^{NM}(h)$. Inserting this output level into the firm's profit, we find that $\pi_i^{NM}(h) = \frac{2+h}{2}\left(\frac{1-c-t}{3+h}\right)^2 + tz_i$, which decreases in h since $\frac{\partial \pi_i^{NM}(h)}{\partial h} = -\frac{(1+h)(1-c-t)^2}{2(3+h)^2} < 0$.

Under a merger, firms coordinate their output decisions to maximize joint profits, as follows

$$\max_{q_i, q_j \geq 0} \quad \pi_i + \pi_j$$

where profit π_i was defined under no mergers. Differentiating with respect to q_i and q_j, yields $q_i^M(h) = q_j^M(h) = \frac{1-c-t}{4+h}$, which satisfies $q_i^M(h) < q_i^{NM}(h)$ for all parameter values. In particular, the output differential is

$$\Delta q_i(h) \equiv q_i^{NM}(h) - q_i^M(h) = \frac{1-c-t}{(3+h)(4+h)},$$

which decreases as costs become more convex h since $\frac{\partial \Delta q_i(h)}{\partial h} = -\frac{(1-c-t)(7+2h)}{(3+h)^2(4+h)^2} < 0$. Therefore, the merger reduces output more significantly when firms face linear than convex costs. Aggregate output in this setting becomes $Q^M(h) = 2q_i^M(h)$. Equilibrium profits with a merger are, then, $\pi_i^M(h) = \frac{4+h}{2}\left(\frac{1-c-t}{4+h}\right)^2 + tz_i$, which decreases in h since $\frac{\partial \pi_i^M(h)}{\partial h} = -\frac{(1-c-t)^2}{2(4+h)^2} < 0$.

Fourth stage, merger approval. Under no merger, welfare $W_{AA}^{NM}(h) = CS^{NM}(h) + PS^{NM}(h) + T^{NM}(h) - ED_{AA}^{NM}(h)$ evaluated at $Q^{NM}(h)$ is

$$\begin{aligned} W_{AA}^{NM}(h) &= \frac{1}{2}\left(\frac{1-c-t}{3+h}\right)^2 + 2\left[\frac{2+h}{2}\left(\frac{1-c-t}{3+h}\right)^2\right] + tZ - \frac{1}{2}Z^2 \\ &\quad + t\left(\frac{2(1-c-t)}{3+h}\right) - d_{AA}\left(\frac{2(1-c-t)}{3+h} - Z\right)^2 \end{aligned}$$

while under the merger, welfare $W_{AA}^M(h) = CS^M(h) + PS^M(h) + T^M(h) - ED_{AA}^M(h)$ evaluated at $Q^M(h)$ is

$$\begin{aligned} W_{AA}^{M}(h) &= \frac{1}{2}\left(\frac{1-c-t}{2+h}\right)^2 + 2\left[\frac{4+h}{2}\left(\frac{1-c-t}{4+h}\right)^2\right] + tZ - \frac{1}{2}Z^2 \\ &\quad + t\left(\frac{1-c-t}{2+h}\right) - d_{AA}\left(\frac{1-c-t}{2+h} - Z\right)^2 \end{aligned}$$

implying that the merger is welfare improving, $W_{AA}^M(h) \geq W_{AA}^{NM}(h)$, if and only if

$$d_{AA} \geq \overline{d}_{AA}(t, Z, h) \equiv \frac{(10+3h)(1-c) + (2+h)(7+2h)Z}{4(7+2h)(1-c-t) - 4(3+h)(4+h)Z}.$$

Cutoff $\overline{d}_{AA}(t, Z, h)$ coincides with that in Lemma 3 when costs are linear, $\overline{d}_{AA}(t, Z, 0) = \frac{5(1-c)+7t}{2[7(1-c-t)-12Z]}$. In addition, $\overline{d}_{AA}(t, Z, h) > 0$ if and only if its denominator is positive, which holds when $Z < Z(h) \equiv \frac{(7+2h)(1-c-t)}{(3+h)(4+h)}$. Cutoff $Z(h)$ is decreasing in h since $\frac{\partial Z(h)}{\partial h} = -\frac{(1-c-t)[25+2h(7+h)]}{(3+h)^2(4+h)^2}$, implying that condition $Z < Z(h)$ becomes more demanding as costs are more convex (higher h).

Furthermore, cutoff $\overline{d}_{AA}(t, Z, h)$ satisfies $\frac{\partial \overline{d}_{AA}(t,Z,h)}{\partial t} = \frac{(3+h)(4+h)(7+2h)[2(1-c)-(2+h)Z]}{4[(7+2h)(1-c-t)-(3+h)(4+h)Z]^2} > 0$, which holds for all $Z < \frac{2(1-c)}{2+h}$, where $Z(h) < \frac{2(1-c)}{2+h}$, entailing that $Z < \frac{2(1-c)}{2+h}$ holds by initial condition $Z < Z(h)$. Similarly, cutoff $\overline{d}_{AA}(t, Z, h)$ increases in Z, c, and h since $\frac{\partial \overline{d}_{AA}(t,Z,h)}{\partial Z} = \frac{(3+h)(4+h)[(1-c)(10+3h)+(2+h)(7+2h)t]}{4[(7+2h)(1-c-t)-(3+h)(4+h)Z]^2} > 0$, $\frac{\partial \overline{d}_{AA}(t,Z,h)}{\partial c} = \frac{(3+h)(4+h)[2t(7+2h)+(10+3h)Z]}{4[(7+2h)(1-c-t)-(3+h)(4+h)Z]^2} > 0$, and $\frac{\partial \overline{d}_{AA}(t,Z,h)}{\partial h} = \frac{(1-c-t)\left[1-c+(7+2h)^2t+(34+h(20+3h))Z\right]}{4[(7+2h)(1-c-t)-(3+h)(4+h)Z]^2} > 0$, respectively.

Third stage, merger submission. Setting $\left(\pi_i^M + \pi_j^M\right) - \left(\pi_i^{NM} + \pi_j^{NM}\right)$, where profits π_i^M and π_i^{NM} were identified in Lemma 1, we obtain that $\left(\pi_i^M + \pi_j^M\right) - \left(\pi_i^{NM} + \pi_j^{NM}\right) = \frac{(1-c-t)^2}{(3+h)^2(4+h)^2}$, which is unambiguously positive and simplifies to $\frac{(1-c-t)^2}{36}$ when costs are linear, $h = 0$. Therefore, firms submit a merger request under all admissible parameters. In addition, the profit gain $PG(h) = \left(\pi_i^M + \pi_j^M\right) - \left(\pi_i^{NM} + \pi_j^{NM}\right)$ satisfies $\frac{\partial PG(h)}{\partial h} = -\frac{2(7+2h)(1-c-t)^2}{(3+h)^3(4+h)^3} < 0$, implying that firms have less incentives to merge when their costs are convex than linear.

Second stage, emission fee. *Merger.* If $d_{AA} \geq \overline{d}_{AA}(t, Z, h)$ holds, the EPA anticipates a merger approval, choosing a fee t that maximizes welfare $W^{NM}(h)$, which yields $t^M(h) = t^M - \frac{(2d-1)(1-c+2dZ)}{(2d+1)[2(2d+1)+h]}h$, where $t^M = \frac{(2d-1)(1-c)-4dZ}{2d+1}$ denotes the emission fee under linear costs. Since ratio $\frac{(2d-1)(1-c+2dZ)}{(2d+1)[2(2d+1)+h]} > 0$, fee $t^M(h)$ is less stringent under convex than linear costs, $t^M(h) < t^M$.

Fee $t^M(h)$ is positive for all $d > d^M(h) \equiv \frac{1-c}{2(1-c)-(4+h)Z}$, where cutoff $d^M(h)$ is positive if $Z < \frac{1-c}{4+h}$, and $d^M(h)$ unambiguously decreases in h. In addition, fee $t^M(h)$ satisfies $\frac{\partial t^M(h)}{\partial d} = \frac{2(4+h)[2(1-c)-(2+h)Z]}{[2(2d+1)+h]^2} > 0$ since $Z < \frac{2(1-c)}{2+h}$ by definition; $\frac{\partial t^M(h)}{\partial Z} = -\frac{2d(4+h)}{2(2d+1)+h} < 0$; $\frac{\partial t^M(h)}{\partial c} = -\frac{2(2d-1)}{2(2d+1)+h} < 0$ since $d \geq 1/2$ by definition; and $\frac{\partial t^M(h)}{\partial h} = -\frac{2(2d-1)(1-c+2dZ)}{[2(2d+1)+h]^2} < 0$.

No merger. If $d_{AA} < \overline{d}_{AA}(t, Z, h)$ holds, the EPA anticipates no merger being submitted or approved, and chooses a fee t that maximizes welfare $W^M(h)$, which yields $t^{NM}(h) = t^{NM} - \frac{(4d-1)(1-c+2dZ)}{2(2d+1)[2(2d+1)+h]}h$, where $t^{NM} = \frac{(4d-1)(1-c)-6dZ}{2(2d+1)}$ denotes the emission fee under linear costs. Since ratio $\frac{(4d-1)(1-c+2dZ)}{2(2d+1)[2(2d+1)+h]} > 0$, fee $t^{NM}(h)$ is less stringent under convex than linear costs, $t^{NM}(h) < t^M$.

Fee $t^{NM}(h)$ is positive for all $d > d^{NM}(h) \equiv \frac{1-c}{4(1-c)-2(3+h)Z}$, where cutoff $d^{NM}(h)$ is positive if $Z < \frac{2(1-c)}{3+h}$, and $d^{NM}(h)$ unambiguously decreases in h. In addition, fee $t^{NM}(h)$ satisfies $\frac{\partial t^{NM}(h)}{\partial d} = \frac{2(3+h)[2(1-c)-(2+h)Z]}{[2(2d+1)+h]^2} > 0$ since $Z < \frac{2(1-c)}{2+h}$ by definition; $\frac{\partial t^{NM}(h)}{\partial Z} = -\frac{2d(3+h)}{2(2d+1)+h} < 0$; $\frac{\partial t^{NM}(h)}{\partial c} = -\frac{4d-1}{2(2d+1)+h} < 0$ since $d \geq 1/2$ by definition; and $\frac{\partial t^{NM}(h)}{\partial h} = -\frac{(4d-1)(1-c+2dZ)}{[2(2d+1)+h]^2} < 0$.

Finding cutoff Z^{Min}. Evaluating cutoff $\overline{d}_{AA}(t, Z, h)$ at fee $t^M(h)$, we obtain

$$\overline{d}_{AA}(t^M(h), Z, h) = \frac{(1-c)\left[2+h-8d(3+h)\right] + 2d(2+h)(7+2h)Z}{4Z\left[(2+h)(3+h)-2d\right] - 4(1-c)(7+2h)}.$$

We now set $d_{AA} = \overline{d}_{AA}(t^M(h), Z, h)$ and solve for Z to find the minimal aggregate abatement that induces a merger approval,

$$Z < Z^{Min}(h) \equiv \frac{(1-c)\left[2+h-8d(3+h)+d_{AA}(28+8h)\right]}{2d(2h^2+11h+4d_{AA}+14) - 4d_{AA}(2+h)(3+h)}.$$

When costs are linear, $h = 0$, cutoff $Z^{Min}(h)$ coincides with that in Corollary 3, $Z^{Min}(0) = Z^{Min} \equiv \frac{(1-c)(12d-14d_{AA}-1)}{2[7d+2d_{AA}(d-3)]}$. The comparative statics of cutoff $Z^{Min}(h)$ are

$$\begin{aligned}
\frac{\partial Z^{Min}(h)}{\partial d} &= \frac{(1-c)(7+2h)\left[2(2d_{AA}+1)+h\right]^2}{2\left[d(14+h(11+2h)+4d_{AA}-2d_{AA}(2+h)(3+h)\right]^2} > 0, \\
\frac{\partial Z^{Min}(h)}{\partial d_{AA}} &= -\frac{(1-c)(3+h)\left[2(2d_{AA}+1)+h\right]^2}{2\left[d(14+h(11+2h)+4d_{AA}-2d_{AA}(2+h)(3+h)\right]^2} < 0, \text{ and}
\end{aligned}$$

$$\frac{\partial Z^{Min}(h)}{\partial h} = \frac{(1-c)(d-d_{AA})\left[4-4d(19+2h(6+h)-4d_{AA})\right] + 92d_{AA} + h[4+h+8d_{AA}(7+h)]}{2\left[d(14+h(11+2h)+4d_{AA}-2d_{AA}(2+h)(3+h)\right]^2},$$

which is positive when its numerator is positive, which holds if and only if $d_{AA} > d_{AA}^{ZMin}(h) \equiv \frac{d[76-8h(6+h)]-(2+h)^2}{92+16+8h(7+h)}$. Cutoff $d_{AA}^{ZMin}(h)$ lies below the 45-degree line since the difference $d - d_{AA}^{ZMin}(h) = \frac{[2(2d+1)+h]^2}{92+16+8h(7+h)} > 0$.

First stage, abatement. *No merger.* Anticipating no merger, which holds if $Z < Z^{Min}(h)$, every firm i has best response function

$$z_i^{NM}(z_j) = \frac{(1-c)\left[(2+h)-2d(4+8d+3h)\right]}{(2+h)^2+4d^2(14+3h)+4d(2+h)(5+h)} - \frac{2d\left[(2+h)(3+h)+2d(4+h)\right]}{(2+h)^2+4d^2(14+3h)+4d(2+h)(5+h)}z_j.$$

Invoking symmetry, $z_i = z_j$, yields an abatement level of $z_i^{NM}(h) = \frac{(1-c)[2+h-2d(4+8d+3h)]}{(2+h)^2+8d^2(9+2h)+2d(2+h)(13+3h)}$, which is positive for all $h > \widetilde{h}_{NM} \equiv \frac{2-8d(2d+1)}{6d-1}$. Cutoff $\widetilde{h}_{NM}$ originates at $h = -3$ when $d = 1/2$, and unambiguously decreases in d since $\frac{\partial \widetilde{h}_{NM}}{\partial d} = -\frac{4(24d^2-8d+1)}{(6d-1)^2} < 0$ given that $d \geq 1/2$ by definition. Therefore, condition $h > \widetilde{h}_{NM}$ holds for all admissible values of $h \geq 0$, implying that individual abatement $z_i^{NM}(h) > 0$ under all admissible parameters.

When costs are linear, $h = 0$, individual abatement coincides with that in Proposition 1, $z_i^{NM}(0) = z_i^{NM} \equiv \frac{(1-c)[4d(2d+1)-1]}{2(1+13d+18d^2)}$. In addition, $z_i^{NM}(h)$ satisfies

$$\frac{\partial z_i^{NM}(h)}{\partial d} = \frac{2(1-c)[8d^2(16+3h)+8d(2+h)(13+4h)+(2+h)^2(17+6h)]}{\left[(2+h)^2+8d^2(9+2h)+2d(2+h)(13+3h)\right]^2} > 0,$$

$\frac{\partial z_i^{NM}(h)}{\partial c} = -\frac{2d[4(2d+1)+3h]-(2+h)}{\left[(2+h)^2+8d^2(9+2h)+2d(2+h)(13+3h)\right]^2} < 0$ since $h > \widetilde{h}_{NM}$ holds for all admissible parameters as shown above, and

$$\frac{\partial z_i^{NM}(h)}{\partial h} = \frac{(1-c)\left[256d^4-8d(2+h)-(2+h)^2+16d^3(19+2h)+4d^2(24+h(32+9h))\right]}{\left[(2+h)^2+8d^2(9+2h)+2d(2+h)(13+3h)\right]^2} < 0$$

given that $d \geq 1/2$ and $h \geq 0$ by definition. Furthermore, $z_i^{NM}(h)$ is compatible with the premise $Z < Z^{Min}(h)$ if $Z^{NM}(h) = z_i^{NM}(h) + z_i^{NM}(h) < Z^{Min}(h)$, which holds if and only if

$$d_{AA} < d_{AA}^{NM}(h) \equiv \frac{16d^2(4h+13)+10d(h+2)(h+3)-(h+2)^2}{4\left[16d^2+26d(h+3)+(h+2)(4h+13)\right]}$$

where cutoff $d_{AA}^{NM}(h)$ simplifies to $d_{AA}^{NM}(0) = d_{AA}^{NM} = \frac{d(15+52d)-1}{26+2d(39+8d)}$ when costs are linear, $h = 0$, as found in Proposition 1. Otherwise, cutoff $d_{AA}^{NM}(h)$ increases in both d and h.

Merger. Anticipating merger, which holds if $Z \geq Z^{Min}(h)$, every firm i has best response function

$$z_i^{M}(z_j) = \frac{2(1-c)\left[(2+h)-d(4+8d+3h)\right]}{(2+h)^2+4d^2(16+3h)+4d(2+h)(6+h)} - \frac{2d(4+h)(2+2d+h)}{(2+h)^2+4d^2(16+3h)+4d(2+h)(6+h)}z_j.$$

Invoking symmetry, $z_i = z_j$, yields an abatement level of $z_i^{M}(h) = \frac{(1-c)[2+h-d(4+8d+3h)]}{(2+h)^2+16d^2(5+h)+2d(2+h)(16+3h)}$, which is positive for all $h > \widetilde{h}_{M} \equiv \frac{2-4d(2d+1)}{3d-1}$. Cutoff $\widetilde{h}_{M}$ originates at $h = -4$ when $d = 1/2$, and unambiguously decreases in d since $\frac{\partial \widetilde{h}_M}{\partial d} = -\frac{2(12d^2-8d+1)}{(3d-1)^2} < 0$ given that $d \geq 1/2$ by definition. Therefore, condition $h > \widetilde{h}_M$ holds for all admissible values of $h \geq 0$, implying that individual abatement $z_i^M(h) > 0$ under all admissible parameters.

When costs are linear, $h = 0$, individual abatement coincides with that in Proposition 2, $z_i^M(0) = z_i^M \equiv \frac{(1-c)[2d(2d+1)-1]}{4d(4+5d)+1}$. In addition, $z_i^M(h)$ satisfies $\frac{\partial z_i^M(h)}{\partial d} = \frac{6(1-c)(4+h)(2+4d+h)(6+4d+3h)}{[(2+h)^2+16d^2(5+h)+2d(2+h)(16+3h)]^2} > 0$, $\frac{\partial z_i^M(h)}{\partial c} = -\frac{2[d(4+8d+3h)-2-h]}{(2+h)^2+16d^2(5+h)+2d(2+h)(16+3h)} < 0$ if and only if for all $h > \widetilde{h}_M$, which holds for all admissible parameters as shown above, and

$$\frac{\partial z_i^M(h)}{\partial h} = \frac{2(1-c)\left[128d^4 + 16d^3(11+6h) + 2d^2\left[32 + h(32+9h)\right] - (2+h)^2 - d(2+h)(10+3h)\right]}{\left[(2+h)^2 + 16d^2(5+h) + 2d(2+h)(16+3h)\right]^2} < 0$$

given that $d \geq 1/2$ and $h \geq 0$ by definition. Finally, $z_i^M(h)$ is compatible with the premise $Z \geq Z^{Min}(h)$ if $Z^M(h) = z_i^M(h) + z_i^M(h) \geq Z^{Min}(h)$, which holds if and only if

$$d_{AA} \geq d_{AA}^M(h) \equiv \frac{16d^2(5h+16) + 2d(h+2)(9h+26) - (h+2)^2}{4\left[16d^2 + 2d(15h+46) + (h+2)(6h+19)\right]}$$

where cutoff $d_{AA}^M(h)$ reduces to $d_{AA}^M(0) = d_{AA}^M = \frac{d(26+64d)-1}{4d(23+4d)+38}$ when costs are linear, $h = 0$, as found in Proposition 2. Otherwise, cutoff $d_{AA}^M(h)$ increases in both d and h.

7.4 Proof of Lemma 1

Under no merger, every firm i independently chooses its output q_i to solve

$$\max_{q_i \geq 0} \ \pi_i = (1 - q_i - q_j)q_i - cq_i - t(q_i - z_i)$$

Differentiating with respect to q_i, yields best response function $q_i(q_j) = \frac{1-c-t}{2} - \frac{1}{2}q_j$. Firm j's best response function is analogous. In a symmetric equilibrium, $q_i = q_j = q_i^{NM}$, we obtain that $q_i^{NM} = \frac{1-c-t}{2} - \frac{1}{2}q_i^{NM}$. Solving for q_i^{NM}, yields $q_i^{NM} = \frac{1-c-t}{3}$. Aggregate output in this setting becomes $Q^{NM} = 2q_i^{NM}$. Inserting this output level into the firm's profit, we find that $\pi_i^{NM} = \left(\frac{1-c-t}{3}\right)^2 + tz_i = (q_i^{NM})^2 + tz_i$.

Under a merger, firms coordinate their output decisions to maximize joint profits, as follows

$$\max_{q_i, q_j \geq 0} \quad \pi_i + \pi_j$$

where profit π_i was defined under no mergers. Differentiating with respect to q_i and q_j, yields $q_i^M = q_j^M = \frac{1-c-t}{4}$, which satisfies $q_i^M < q_i^{NM}$ for all parameter values. Aggregate output in this setting becomes $Q^M = 2q_i^M$. Equilibrium profits with a merger are, then, $\pi_i^M = \frac{(1-c-t)^2}{8} + tz_i = 2(q_i^M)^2 + tz_i$.

7.5 Proof of Lemma 2

Under no merger, welfare $W_{AA}^{NM} = CS^{NM} + PS^{NM} + T^{NM} - ED_{AA}^{NM}$ evaluated at Q^{NM} is

$$\begin{aligned} W_{AA}^{NM} &= \frac{1}{2}\left(\frac{1-c-t}{3}\right)^2 + 2\left(\frac{1-c-t}{3}\right)^2 + tZ - \frac{1}{2}Z^2 \\ &+t\left(\frac{2(1-c-t)}{3}\right) - d_{AA}\left(\frac{2(1-c-t)}{3} - Z\right)^2 \end{aligned}$$

while under the merger, welfare $W_{AA}^{M} = CS^{M} + PS^{M} + T^{M} - ED_{AA}^{M}$ evaluated at Q^{M} is

$$\begin{aligned} W_{AA}^{M} &= \frac{1}{2}\left(\frac{1-c-t}{2}\right)^2 + 2\frac{(1-c-t)^2}{8} + tZ - \frac{1}{2}Z^2 \\ &+t\left(\frac{1-c-t}{2}\right) - d_{AA}\left(\frac{1-c-t}{2} - Z\right)^2 \end{aligned}$$

implying that $W_{AA}^{M} \geq W_{AA}^{NM}$ if and only if $d_{AA} \geq \overline{d}_{AA}(t,Z) \equiv \frac{5(1-c)+7t}{2[7(1-c-t)-12Z]}$. Cutoff $\overline{d}_{AA}(t,Z) > 0$ if and only if $Z < \frac{7(1-c-t)}{12}$, reaching its lowest value at $t = 0$, where $\frac{7(1-c)}{12}$. Comparing $Z < \frac{7(1-c-t)}{12}$ against the initial condition $Z < \frac{1-c}{2}$, we obtain that $\frac{7(1-c)}{12} - \frac{1-c}{2} = \frac{1-c}{12} > 0$, which implies that $\frac{7(1-c-t)}{12} > \frac{1-c}{2}$, and condition $Z < \frac{7(1-c-t)}{12}$ unambiguously holds given the initial condition $Z < \frac{1-c}{2}$.

Comparative statics. In addition, cutoff $\overline{d}_{AA}(t,Z)$ satisfies $\frac{\partial \overline{d}_{AA}(t,Z)}{\partial t} = \frac{42(1-c+Z)}{[7(1-c-t)-12Z]^2}$, which is positive since $Z < \frac{1-c}{2}$ holds by definition. Finally, $\overline{d}_{AA}(t,Z)$ satisfies $\frac{\partial \overline{d}_{AA}(t,Z)}{\partial Z} = \frac{6[5(1-c)+7t]}{[7(1-c-t)-12Z]^2} > 0$ and $\frac{\partial \overline{d}_{AA}(t,Z)}{\partial c} = \frac{42t+30Z}{[7(1-c-t)-12Z]^2} > 0$.

7.6 Proof of Lemma 3

Setting $\left(\pi_i^M + \pi_j^M\right) - \left(\pi_i^{NM} + \pi_j^{NM}\right)$, where profits π_i^M and π_i^{NM} were identified in Lemma 1, we obtain that $\left(\pi_i^M + \pi_j^M\right) - \left(\pi_i^{NM} + \pi_j^{NM}\right) = \frac{2(1-c-t)^2}{8} - 2\left(\frac{1-c-t}{3}\right)^2 = \frac{(1-c-t)^2}{36}$, which is unambiguously positive. Therefore, $\left(\pi_i^M + \pi_j^M\right) > \left(\pi_i^{NM} + \pi_j^{NM}\right)$ holds under all admissible parameters.

7.7 Proof of Lemma 4

Merger. If $d_{AA} \geq \overline{d}_{AA}(t,Z)$ holds, the EPA anticipates that firms will submit a merger request (as shown in Lemma 3) and the EPA to respond approving it (as shown in Lemma 2). The EPA, then, chooses the emission fee that maximizes social welfare under a merger, that is,

$$\begin{aligned} \max_{t\geq 0}\; W^{M} &= \frac{1}{2}\left(\frac{1-c-t}{4}\right)^2 + 2\left(\frac{1-c-t}{4}\right)^2 + tZ - \frac{1}{2}Z^2 \\ &+t\left(\frac{2\,(1-c-t)}{4}\right) - d\left(\frac{2\,(1-c-t)}{4} - Z\right)^2 \end{aligned}$$

Differentiating with respect to t, and solving for t, yields a fee $t^M = \frac{(2d-1)(1-c)-4dZ}{2d+1}$, which is positive for all $d > d^M \equiv \frac{1-c}{2(1-c-2Z)}$, where cutoff d^M is positive since $Z < \frac{1-c}{2}$ by definition. In addition, fee t^M satisfies $\frac{\partial t^M}{\partial d} = \frac{4(1-c-Z)}{(2d+1)^2} > 0$ since $Z < \frac{1-c}{2}$ by assumption; $\frac{\partial t^M}{\partial Z} = -\frac{4d}{2d+1} < 0$; and $\frac{\partial t^M}{\partial c} = -\frac{2d-1}{2d+1} < 0$ since $d \geq 1/2$ by definition.

No merger. If, instead, $d_{AA} < \overline{d}_{AA}(t, Z)$ holds, the EPA anticipates that a merger will not ensue in subsequent stages, and chooses t to solve

$$\begin{aligned} W^{NM} \;&=\; \frac{1}{2}\left(\frac{1-c-t}{3}\right)^2 + 2\left(\frac{1-c-t}{3}\right)^2 + tZ - \frac{1}{2}Z^2 \\ &\quad + t\left(\frac{2(1-c-t)}{3}\right) - d\left(\frac{2(1-c-t)}{3} - Z\right)^2 \end{aligned}$$

Differentiating with respect to t, and solving for t, yields a fee $t^{NM} = \frac{(4d-1)(1-c)-6dZ}{2(2d+1)}$, which is positive for all $d > d^{NM} \equiv \frac{1-c}{2[2(1-c)-3Z]}$, where cutoff d^{NM} is positive since $Z < \frac{1-c}{2}$ by definition. In addition, the fee differential is $t^{NM} - t^M = \frac{1-c+2dZ}{2(2d+1)}$, being unambiguously positive. Furthermore, fee t^{NM} satisfies $\frac{\partial t^{NM}}{\partial d} = \frac{3(1-c-Z)}{(2d+1)^2} > 0$ since $Z < \frac{1-c}{2}$ by assumption; $\frac{\partial t^{NM}}{\partial Z} = -\frac{3d}{2d+1} < 0$; and $\frac{\partial t^M}{\partial c} = -\frac{4d-1}{2(2d+1)} < 0$ since $d \geq 1/2$ by definition.

EPA's decision. Cutoff $\overline{d}_{AA}(t, Z)$, evaluated at fees t^M and t^{NM} satisfies $\overline{d}_{AA}(t^{NM}, Z) > \overline{d}_{AA}(t^M, Z)$ since $\overline{d}_{AA}(t, Z)$ is increasing in t (see Lemma 2). These two cutoffs give rise to three regions: (i) when $d_{AA} < \overline{d}_{AA}(t^M, Z)$, the AA responds rejecting the merger, both after fee t^M and t^{NM}; (ii) when $\overline{d}_{AA}(t^M, Z) \leq d_{AA} < \overline{d}_{AA}(t^{NM}, Z)$, the AA responds approving the merger after the EPA sets fee t^M, but rejecting it after t^{NM}; and (iii) otherwise, the AA responds approving the merger, both after fee t^M and t^{NM}. In region (i), the EPA's sets fee t^{NM}, while in region (iii), it sets fee t^M. In region (ii), however, the EPA could set a fee t^M, inducing a merger, or t^{NM}, which induces no mergers. Both fees induce, nonetheless, the same aggregate output in equilibrium, $Q^{NM}(t^{NM}) = Q^M(t^M) = \frac{(1-c)+2dZ}{2d+1}$, yielding the same social welfare. As a consequence, the EPA optimally sets t^M in regions (ii) and (iii), and fee t^{NM} in region (i).

7.8 Proof of Corollary 1

Evaluating cutoff $d_{AA}(t, Z)$ at fee t^M, we obtain $d_{AA}(t^M, Z) = \frac{(1-c)(12d-1)-14dZ}{14(1-c)-4Z(3-d)}$, where the numerator is positive if $(1-c) > \frac{14d}{12d-1}Z$, which holds since $Z < \frac{1-c}{2}$ by definition, and $\frac{14d}{12d-1} < 2$ for all admissible values of d. Similarly, the denominator of $d_{AA}(t^M, Z)$ is positive if $(1-c) > \frac{4(3-d)}{14}Z$, which holds since $Z < \frac{1-c}{2}$ by definition, and $\frac{4(3-d)}{14} < 2$ for all admissible values of d.

In addition, cutoff $d_{AA}(t^M, Z)$ is lower than d since $d - d_{AA}(t^M, Z) = \frac{(2d+1)[1-c+2dZ]}{14(1-c)-4Z(3-d)}$, where the numerator is unambiguously positive, and the denominator is positive by the same argument as above. Then, $d_{AA}(t^M, Z) < d$ for all admissible parameters.

Furthermore, cutoff $d_{AA}(t^M, Z)$ originates at $d_{AA}(t^M, 0) = \frac{12d-1}{14}$ when $Z = 0$, and decreases in Z since $\frac{\partial d_{AA}(t^M,Z)}{\partial Z} = -\frac{3(1-c)(2d+1)^2}{[7(1-c)-2Z(3-d)]^2} < 0$. Finally, cutoff $d_{AA}(t^M, Z)$ satisfies $\frac{\partial d_{AA}(t^M,Z)}{\partial d} = \frac{42[1-c-Z]^2}{[7(1-c)-2Z(3-d)]^2} > 0$ and $\frac{\partial d_{AA}(t^M,Z)}{\partial c} = -\frac{3Z(2d+1)^2}{[7(1-c)-2Z(3-d)]^2} < 0$.

7.9 Proof of Corollary 2

The minimal investment that induces a merger, $Z^{Min} \equiv \frac{(1-c)(12d-14d_{AA}-1)}{2[7d+2d_{AA}(d-3)]}$, is positive for all $2d - 14d_{AA} - 1 > 0$ or, after solving for d_{AA}, $d_{AA} < \widehat{d}_{AA} \equiv \frac{12d-1}{14}$. (The term in the denominator, $7d+2d_{AA}(d-3)$, is positive for all admissible parameter values, since $d \geq d_{AA}$, by definition.) Cutoff $\widehat{d}_{AA}$ originates at $d_{AA} = 0.36$ when $d = 1/2$, increases in d, and lies unambiguously below the 45-degree line since $d - \widehat{d}_{AA} = \frac{1+2d}{14} > 0$. In addition, Z^{Min} satisfies $\frac{\partial Z^{Min}}{\partial d} = \frac{7(1-c)(1+2d_{AA})^2}{2(1+\beta)[7d+2d_{AA}(d-3)]^2} > 0$ and $\frac{\partial Z^{Min}}{\partial d_{AA}} = -\frac{7(1-c)(1+2d_{AA})^2}{(1+\beta)[7d+2d_{AA}(d-3)]^2} < 0$.

7.10 Proof of Proposition 1

Anticipating no merger, which holds if $Z < Z^{Min}$, every firm i has best response function $z_i^{NM}(z_j) = \frac{(1-c)[4d(2d+1)-1]}{4d(5+7d)+2} - \frac{d(3+4d)}{2d(5+7d)+1} z_j$, as shown in section 3.3. Invoking symmetry, $z_i = z_j$, yields an abatement level of $z_i^{NM} = \frac{(1-c)[4d(2d+1)-1]}{2(1+13d+18d^2)}$, which is positive since $d \geq 1/2$ by definition, and satisfies $\frac{\partial z_i^{NM}}{\partial d} = \frac{(1-c)[17+4d(13+8d)]}{2[1+d(13+18d)]^2} > 0$ and $\frac{\partial z_i^{NM}}{\partial c} = -\frac{4d(2d+1)-1}{2(1+13d+18d^2)} < 0$. In addition, aggregate abatement, $Z^{NM} = z_i^{NM} + z_j^{NM}$, satisfies $Z^{NM} < \frac{1-c}{2}$ since $\frac{1-c}{2} - Z^{NM} = \frac{(1-c)(1+d)(3+2d)}{2(1+13d+18d^2)} > 0$.

For z_i^{NM} to be an equilibrium abatement, we need it to satisfy two conditions: (i) it must induce no merger; and (ii) no firm has unilateral incentives to deviate to induce a merger. We separately analyze each condition below.

Condition (i). Evaluating aggregate abatement, $Z^{NM} = z_i^{NM} + z_j^{NM}$, we obtain that it is compatible with the initial condition $Z < Z^{Min}$ if $Z^{NM} < Z^{Min}$, which holds if and only if $d_{AA} < d_{AA}^{NM} \equiv \frac{d(15+52d)-1}{26+2d(39+8d)}$. Cutoff d_{AA}^{NM} originates at $d_{AA} = 0.28$ when $d = 1/2$, increases in d since $\frac{\partial d_{AA}^{NM}}{\partial d} = \frac{9[13+2d(38+53d)]}{[13+d(39+8d)]^2} > 0$, and satisfies $\widehat{d}_{AA} - d_{AA}^{NM} = \frac{3(1+2d)[4d(2d+1)-1]}{7(8d^2+39d+13)} > 0$. Since $d > \widehat{d}_{AA}$ from Corollary 2, we obtain that the cutoff ranking is $d > \widehat{d}_{AA} > d_{AA}^{NM}$.

Condition (ii). If firm i chooses z_i^{NM} and induces no merger, its profits are $\pi_i^{NM}(z_i^{NM}, z_j^{NM}) = \frac{(1-c)^2(2+5d)[1+d(5+8d(3+4d)]}{4[1+d(13+18d)]^2}$. Firm i can, instead, take its rival's abatement level as given at z_j^{NM}, and unilaterally deviate from z_i^{NM} to $z_i^{Dev,a} \equiv Z^{Min} - z_j^{NM}$, inducing a merger approval. This deviation implies that aggregate abatement increases from Z^{NM} to Z^{Min}, where $Z^{NM} < Z^{Min}$ holds since $d_{AA} < d_{AA}^{NM}$ in this case. Choosing the deviation abatement level

$$\begin{aligned} z_i^{Dev,a} &= Z^{Min} - z_j^{NM} \\ &= \frac{1-c}{2}\left(\frac{12d - 14d_{AA} - 1}{7d + 2d_{AA}(d-3)} - \frac{4d(2d+1)-1}{18d^2 + 13d + 1}\right) \end{aligned}$$

yields a merger profit of

$$\pi_i^M(z_i^{Dev,a}, z_j^{NM}) = \frac{(1-c)^2\left[2d_{AA}d(49 + 4d(123 + d(199 + 50d))) - 3) - C\right]}{2[1 + d(13 + 18d)][7d + 2d_{AA}(d-3)]^2}$$

where term $C \equiv 2d_{AA}^2(51+d(371+2d(315+2d(65+4d))))+d(5-4d(3+d(79+119d)))$. Comparing these two profits, we obtain that $\pi_i^{NM}(z_i^{NM}, z_j^{NM}) > \pi_i^M(z_i^{Dev,a}, z_j^{NM})$ for all admissible parameters. Therefore, firm i has no incentives to unilaterally deviate, even if such a deviation induces a merger.

7.11 Proof of Proposition 2

Anticipating a merger, which holds if $Z \geq Z^{Min}$, every firm i's best response function is $z_i^M(z_j) = \frac{(1-c)[2d(2d+1)-1]}{4d(3+4d)+1} - \frac{4d(1+d)}{4d(3+4d)+1}z_j$, as shown in section 3.3. Invoking symmetry, $z_i = z_j$, yields an abatement level of $z_i^M = \frac{(1-c)[2d(2d+1)-1]}{4d(4+5d)+1}$, which is positive since $d \geq 1/2$ by definition, and satisfies $\frac{\partial z_i^M}{\partial d} = \frac{6(1-c)[3+4d(2+d)]}{[4d(4+5d)+1]^2} > 0$ and $\frac{\partial z_i^{NM}}{\partial c} = -\frac{2d(2d+1)-1}{4d(4+5d)+1} < 0$. In addition, aggregate abatement, $Z^M = z_i^M + z_j^M$, satisfies $Z^M < \frac{1-c}{2}$ since $\frac{1-c}{2} - Z^M = \frac{(1-c)[5+4d(2+d)]}{8d(4+5d)+2} > 0$.

For z_i^M to be an equilibrium abatement, we need it to satisfy two conditions: (i) it must induce no merger; and (ii) no firm has unilateral incentives to deviate to induce a merger. We separately analyze each condition below.

Condition (i). Evaluating aggregate abatement $Z^M = z_i^M + z_j^M$, we find that it is compatible with the initial condition $Z \geq Z^{Min}$ if $Z^M \geq Z^{Min}$, which holds if and only if $d_{AA} \geq d_{AA}^M \equiv \frac{d(26+64d)-1}{4d(23+4d)+38}$. Cutoff d_{AA}^M originates at $d_{AA} = 0.32$ when $d = 1/2$, increases in d since $\frac{\partial d_{AA}^M}{\partial d} = \frac{18(2d+1)(38d+15)}{[8d^2+46d+19]^2} > 0$, and satisfies $\widehat{d}_{AA} - d_{AA}^M = \frac{6[8d^2(1+d)-1]}{7(8d^2+46d+19)} > 0$ since $d \geq 1/2$ by definition, and $d_{AA}^M - d_{AA}^{NM} = \frac{3(2d+1)[1+4d(2+d(3+2d))]}{[8d^2+46d+19][13+d(39+8d)]} > 0$. Therefore, the complete ranking of cutoffs is $d > \widehat{d}_{AA} > d_{AA}^M > d_{AA}^{NM}$.

In addition, z_i^M satisfies $z_i^{NM} - z_i^M = \frac{(1-c)(2d+1)[4d(2+d(3+2d))+1]}{2[4d(4+5d)+1][d(13+18d)+1]} > 0$, implying that $z_i^{NM} > z_i^M$ for all admissible parameters, and that $Z^{NM} > Z^M$ also holds.

Condition (ii). If firm i chooses z_i^M and induces a merger, its profits are $\pi_i^M(z_i^M, z_j^M) = \frac{(1-c)^2[1+2d(7+2d(11+2d(8+5d)]}{[1+4d(4+5d)]^2}$. Firm i can, instead, take its rival's abatement level as given at z_j^M, and unilaterally deviate from z_i^M to $z_i^{Dev,c} \equiv z_j^M - Z^{Min} = \frac{1-c}{2}\left(\frac{4d(2d+1)-2}{1+4d(4+5d)} - \frac{12d-14d_{AA}-1}{7d+2d_{AA}(d-3)}\right)$. This deviation implies that aggregate abatement decreases from Z^M to Z^{Min}, where $Z^M > Z^{Min}$ holds since $d_{AA} \geq d_{AA}^M$ in this setting.

If the AA responds to Z^{Min} approving the merger, then the unilateral deviation to $z_i^{Dev,c}$ cannot be profitable: under a merger, z_i^M is a mutual best response. If, instead, the AA responds to Z^{Min} blocking the merger or, alternatively, firm i decreases its abatement by $z_i^{Dev,c} + \varepsilon$ where $\varepsilon \to 0$, so aggregate abatement becomes $Z^{Min} - \varepsilon$, this unilateral deviation induces no merger. In this case, the deviation abatement level $z_i^{Dev,c}$ yields a no-merger profit of $\pi_i^{NM}(z_i^{Dev,c}, z_j^M)$, which lies below $\pi_i^M(z_i^M, z_j^M)$ for all admissible parameters.

A similar argument applies to region d, where $Z^{Min} = 0$, entailing that firm i's deviation is to $z_i^{Dev,d} \equiv z_j^M$. For the same reasons as above, this cannot be optimal in region d.

7.12 Proof of Proposition 3

No merger. If firms choose an abatement level z_i^{NM} in region b, the AA responds approving the merger and the EPA responds with fee t^M, yielding profits

$$\pi^M(z_i^{NM}, z_j^{NM}) = \frac{(1-c)^2(1+8d)(5+8d)(1+2d^2)}{8[1+d(13+18d)]^2}$$

Firm i can unilaterally deviate from z_i^{NM}, reducing its abatement to $z_i^{Dev} \equiv z_j^{NM} - Z^{Min}$, still inducing a merger approval, and yielding profits of $\pi^M(z_i^{Dev}, z_j^{NM})$. To compare profits $\pi^M(z_i^{NM}, z_j^{NM})$ and $\pi^M(z_i^{Dev}, z_j^{NM})$, first note that they are both evaluated at z_j^{NM}, and firm i's abatement satisfies $z_i^{NM} > \frac{Z^{Min}}{2} > z_i^M$. Since under merger z_i^M is profit maximizing, by choosing z_i^{Dev} firm i approaches z_i^M more than by selecting z_i^{NM}, implying that the above profits satisfy $\pi^M(z_i^{Dev}, z_j^{NM}) > \pi^M(z_i^{NM}, z_j^{NM})$.

Merger. If firms choose an abatement level z_i^M in region b, the AA responds blocking the merger and the EPA sets emission fee t^{NM}, yielding profits

$$\pi^{NM}(z_i^M, z_j^M) = \frac{(1-c)^2\,[4d(2d+1)+1]}{4[1+4d(4+5d)]}$$

Firm i can unilaterally deviate from z_i^M, increasing its abatement to $z_i^{Dev} \equiv Z^{Min} - z_j^M$, still inducing no merger, and yielding profits of $\pi^{NM}(z_i^{Dev}, z_j^M)$. To compare profits $\pi^{NM}(z_i^M, z_j^M)$ and $\pi^{NM}(z_i^{Dev}, z_j^M)$, first note that they are both evaluated at z_j^M, and firm i's abatement satisfies $z_i^{NM} > \frac{Z^{Min}}{2} > z_i^M$. Since, under no merger, z_i^{NM} is profit maximizing, implying that by choosing z_i^{Dev} firm i approaches z_i^{NM} more than by selecting z_i^M. Therefore, the above profits satisfy $\pi^{NM}(z_i^{Dev}, z_j^M) > \pi^{NM}(z_i^M, z_j^M)$.

In summary, every firm i has incentives to choose z_i^{Dev} in region b, seeking an aggregate abatement that coincides with Z^{Min}. Hence, in equilibrium, individual abatement decisions are $z_i = z_j = \frac{Z^{Min}}{2}$. In that scenario, no firm has unilateral incentives to deviate to a different abatement level. In addition, Z^{Min} satisfies $Z^{Min} < \frac{1-c}{2}$ for all $d_{AA} > \frac{5d-1}{2(4+d)}$, where $\frac{5d-1}{2(4+d)}$ lies below d_{AA}^{NM} since the difference $d_{AA}^{NM} - \frac{5d-1}{2(4+d)} = \frac{3(1+d)(1+2d)(3+2d)}{2(4+d)(8d^2+39d+13)} > 0$, implying that condition $Z^{Min} < \frac{1-c}{2}$ holds for all values of d_{AA} in region b.

Finally, we evaluate the length of region b, we find the difference $d_{AA}^M - d_{AA}^{NM} = \frac{3(2d+1)[1+4d(2+d(3+2d))]}{(8d^2+46d+19)(8d^2+39d+13)} > 0$, which is increasing in d since $\frac{\partial\left(d_{AA}^M - d_{AA}^{NM}\right)}{\partial d} = \frac{9[377+4d(811+2d(1611+2d(1826+d(2269+4d(323+46d)))))]}{(8d^2+46d+19)^2[13+d(39+8d)]^2} > 0$.

References

[1] Acemoglu, D., Aghion, P., Bursztyn, L., and Hemous, D. (2012). The environment and directed technical change. American Economic Review, 102(1), 131–166.

[2] Aghion, P., Dechezleprêtre, A., Hemous, D., Martin, R., and Van Reenen, J. (2016). Carbon taxes, path dependency, and directed technical change: Evidence from the auto industry. Journal of Political Economy, 124(1), 1–51.

[3] Barbieri, S., & Malueg, D. A. (2008). Private Provision of a Discrete Public Good: Continuous-Strategy Equilibria in the Private-Information Subscription Game. Journal of Public Economic Theory, vol. 10(4), 529–545,

[4] Bloomberg (2020) The New Energy Giants Are Renewable Companies. Bloomberg Graphics. November 29th. https://www.bloomberg.com/graphics/2020-renewable-energy-supermajors/.

[5] Böhringer, C., Bye, B., Fæhn, T., and Rosendahl, K. E. (2017). Targeted carbon tariffs: Export response, leakage and welfare, Resource and Energy Economics, vol. 50, 51-73.

[6] Cadsby, C. B., and Maynes, E. (1999). Voluntary provision of threshold public goods with continuous contributions: Experimental evidence. Journal of Public Economics, 71(1), 53–73.

[7] Choi, P.-K., Espinola-Arredondo, A., and Munoz-Garcia, F. (2022) Environmental Policy Helping Antitrust Decisions: Socially excessive and insufficient merger approvals, Resource and Energy Economics, vol. 67, 101267.

[8] Duke Energy (2012) Duke Energy 2011 Sustainability Report, https://www.responsibilityreports.com/HostedData/ResponsibilityReportArchive/d/NYSE_DUK_2011.pdf

[9] EC Competition Merger Brief (2023) “EU Green Mergers & Acquisitions Deals – How Merger Control Contributes to a Sustainable Future, Issue 2/2023, September.

[10] Farrell, J., and Shapiro, C. (1990). Horizontal mergers: An equilibrium analysis. American Economic Review, 80(1), 107–126.

[11] Fischer, C., and Newell, R. G. (2008). Environmental and technology policies for climate mitigation. Journal of Environmental Economics and Management, 55(2), 142–162.

[12] Fowlie, M. and Reguant, M. (2018). Challenges in the measurement of leakage risk. American Economic Review: Papers & Proceedings, 108, 124-129.

[13] Fikru, M. G. and L. Gautier (2016). Mergers in Cournot Markets with Environmental Externality and Product Differentiation. Resource and Energy Economics 45: 124–140.

[14] Gautier, L. and M. G. Fikru (2024) *Handbook of Merger Control and Environmental Policy: Theory and Applications*. Natural Resource Management and Policy, vol. 59. Springer.

[15] Hanawalt, C., Hearn, D, and Field, C. (2024) Recommendations to Update the FTC & DOJ’s Guidelines for Collaborations Among Competitors, Sabin Center for Climate Change Law and Columbia Center on Sustainable Investment, May. Available at: https://scholarship.law.columbia.edu/sabin_climate_change/224.

[16] Katsoulacos, Y., and A. Xepapadeas (1996). Emission Taxes and Market Structure. In C. Carraro, Y. Katsoulacos, and A. Xepapadeas (eds.), *Environmental Policy and Market Structure*, Kluwer Academic Publishers, pp. 13–44

[17] Lambertini, L., Poyago-Theotoky, J., and Tampieri, A. (2017) Cournot competition and "green" innovation: An inverted-U relationship. Energy Economics, vol. 68, 116-123.

[18] Montero, J.-P. (2002) Market Structure and Environmental Innovation. Journal of Applied Economics, 5(2), 293–325.

[19] OECD (2021) "Sustainability and Competition," OECD Roundtables on Competition Policy Papers, No. 262, OECD Publishing, Paris, Available at: https://doi.org/10.1787/18e2061c-en.

[20] OffshoreWind (2017) "Siemens, Gamesa Wrap Up Merger Process, Register New Company," April 3, 2017. https://www.offshorewind.biz/2017/04/03/siemens-gamesa-wrap-up-merger-process-register-new-company/

[21] Palfrey, T. R., and Rosenthal, H. (1984). Participation and the provision of discrete public goods: A strategic analysis. Journal of Public Economics, 24(2), 171–193.

[22] Poyago-Theotoky, J. (2007). The organization of R&D and environmental policy. Journal of Economic Behavior and Organization, 62, 63-75.

[23] Salant, S. W., Switzer, S., and Reynolds, R. J. (1983). Losses from horizontal merger: The effects of an exogenous change in industry structure on Cournot–Nash equilibrium. Quarterly Journal of Economics, 98(2), 185–199.

[24] Strandholm, J., Espinola-Arredondo, A., and Munoz-Garcia, F. (2025) Greener or Cheaper: Economies of Scope in Green R&D, Journal of Environmental Economics and Management, 130, 103107.