Environmental Regulation, Incomplete information, and Game Theory
Day #3 - Adding regulation to signaling models

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  - and add a third player (the regulator)

Uninformed regulators

- Weitzman (1974) discussion of "price vs. quantities."
- Many extensions:
  - Stavins (1996) to allow correlation between benefit and cost uncertainty.
  - Roberts and Spence (1986) to allow for mixed policies (firms receive a quota allocation and a fee for units beyond the quota).
  - Newell and Pizer (2003) to allow for stock externalities which can persist to subsequent periods.
  - Montero (2002) to allow for imperfect enforcement of the policy.
  - For a literature review of the "price vs. quantities" debate, see Phaneuf and Requate (2016).

Uninformed regulators

- Other papers considering an imperfectly informed regulator include Segerson (1988) and Xepapadeas (1991).
- In the area of mechanism design, we can also find many papers dealing with uninformed regulators, such as Farrell (1987).
  - For conservation projects, see Banerjee and Shogren (2012) and Espinola-Arredondo, Munoz-Garcia and Choi (2018).

Uninformed regulators

- Signaling models with uninformed reg.:
  - Denicolo (2008) considers a firm choosing its technology, which signals its cost to the reg., who responds with a more/less stringent policy.
  - Antelo and Loureiro (2009) consider a firm choosing its output, which signals its cost to the reg., who responds with a more/less stringent policy.

- Signaling model with informed reg.:
  - Barigozzi and Villeneuve (2006) consider the signaling role of taxes to uninformed consumers who infer the product health quality (e.g., tobacco)

- What about industries that have been monopolized and publicly owned for a long time (e.g., utilities and oil), but recently privatized?
  - The regulator is informed about the incumbent's cost, while the entrant's info. is less precise.
  - Alternative interpretation: the reg. and inc. have precise info. about how costly it is to comply with env. policy, while entrant does not.
- The potential entrant then receives two signals:
  - The incumbent's output (as in Milgrom and Roberts 1982, and standard limit pricing models in IO)
  - The regulator's emission fee.
- Limit pricing doesn't occur in a regulatory vaccum!

- Espinola-Arredondo and Munoz-Garcia (JEEM, 2013).
- Many questions to answer in this setting:
  - Does the presence of the reg facilitate or hinder the inc's traditional ED practices?
  - Standard models predict overproduction in the separating PBE.
    - Is it emphasized by the presence of env. reg?
  - Env. reg. may then become more beneficial under some settings.
    - That is, the inc's ED practices can lead to more pollution!
  - Measuring the welfare benefit of regulation.

Separating equilibrium

- **Separating PBE**
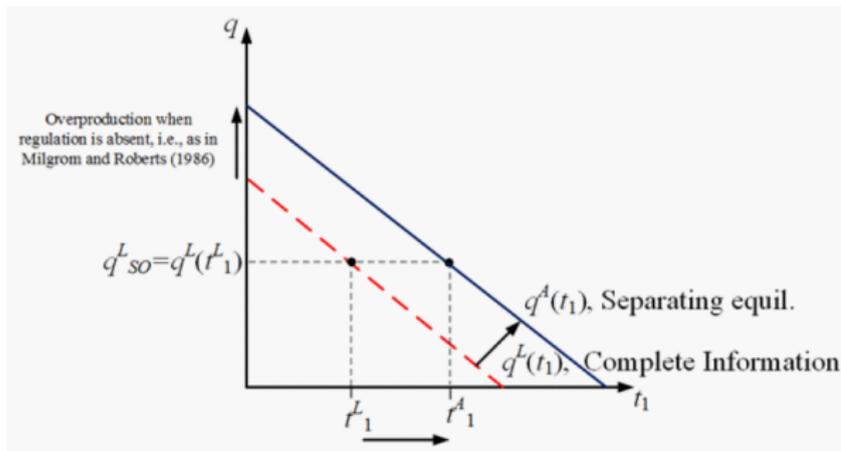
Same output level as under CI, still SO, but a more stringent fee.

- Since output coincides with the SO in both CI and SE, reg. yields the same welfare in both information contexts.
- However, under incomplete info. the incumbent overproduces in the SE, generating a new inefficiency relative to CI.
  - Then, reg. produces larger welfare benefits under incomplete info than under CI...
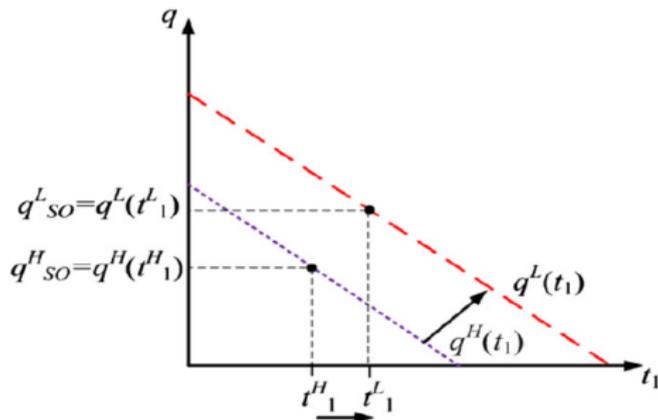 - making reg. more beneficial!

- Welfare benefits from regulation in the separating PBE:
  - decreasing in cost symmetry.
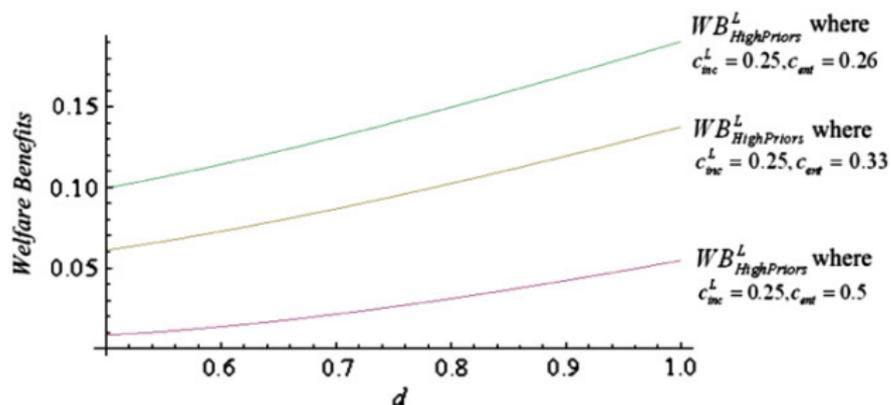
- **Pooling PBE**


In words, ED requires overproduction by the inefficient type of inc and overtaxation by the reg.

- But why would the reg overtax?
  - To deter entry, which is welfare improving if...
  - The entry costs exceed the taxation inefficiencies in the pooling PBE.
- However, the inc. finds overproduction more costly with than without reg.
  - So that reg. hinders its ability to deter entry.

Pooling equilibrium

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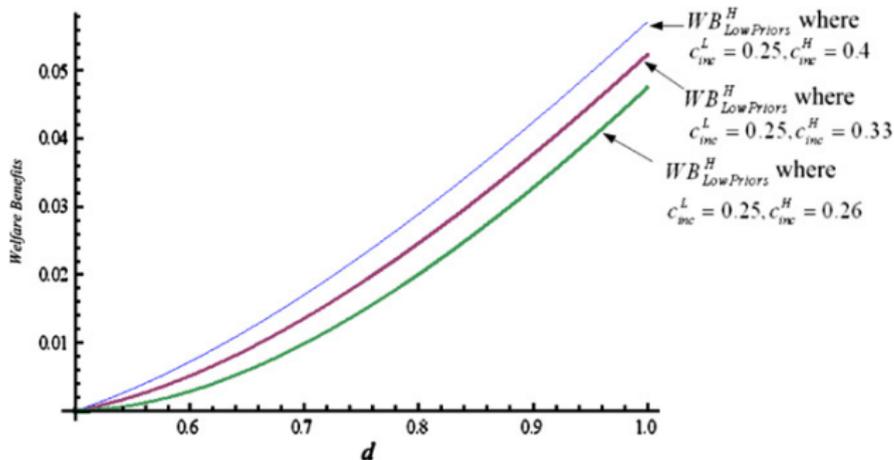
- **Overall results**:
  - Under high priors (SE arises), reg. yields larger WB under II than under CI
    - In short, reg. helps address a new inefficiency that exists under II, yielding SO in both info. contexts.
  - Under low priors (PE arises), reg. yields larger WB under CI than under II
    - In short, reg. creates a new inefficiency (by overtaxing the inc. helping it conceal its type).
    - This can be welfare improving relative to NR, but its WB is smaller than under CI since reg. doesn't yield SO.

Inflexible policy

- The previous paper assumed that regulation can be easily changed across periods.
- But that is quite difficult!
    - *Examples*: Timber yield taxes in California, electricity taxes in Spain, tax on aviation noise pollution in France; among others.
- How does the inflexibility of environmental policy affect our previous results?
- Espinola-Arredondo, Munoz-Garcia, and Bayham (CJE, 2014).

Complete Information

- **Low costs?** No entry. Therefore the regulator sets a constant fee that induces efficient output levels in both periods.
- **High costs?** Entry. The regulator hence wants set:
    - a lax fee on the 1st period monopoly, but
    - a more stringent fee on the 2nd period duopolists.
- But he must choose a single tax!! (Not readjusted upon entry).
    - Hence, any constant fee t produces inefficiencies in one or both periods.
    - The regulator selects a fee that minimizes the sum of these inefficiencies.
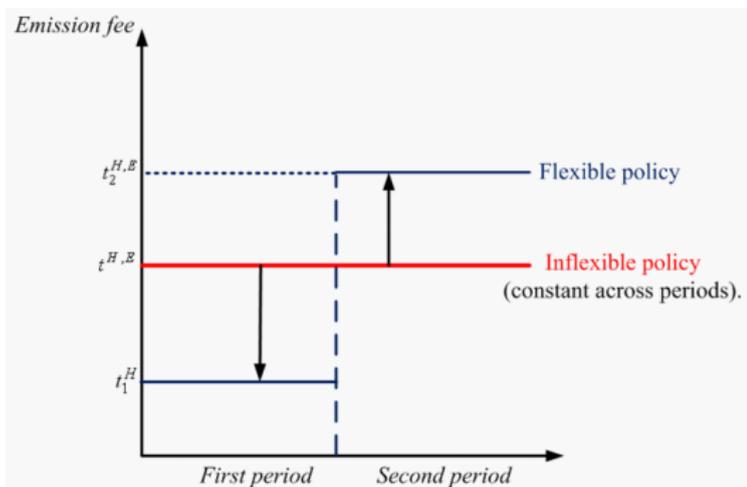
Complete Information - Example

- When $\delta = 1$, the reg. selects $t^{H,E} = \frac{9}{25} t_1^H + \frac{16}{25} t_2^{H,E}$.
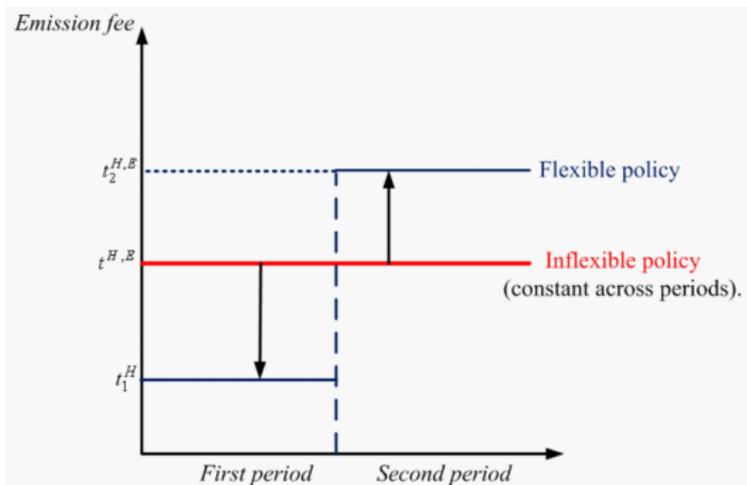
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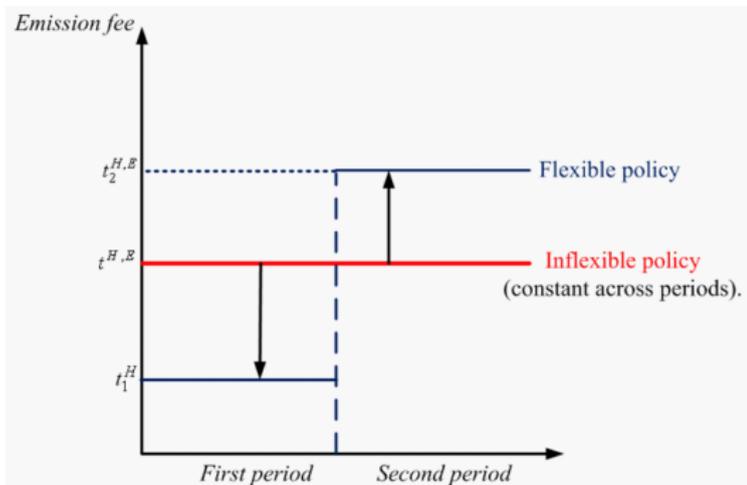
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  - What about Incomplete info?
  - Yes! Emission fees can help conceal info., thus deterring entry.

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4. **Second period:**
   1. If entry does not occur (NE), the incumbent responds producing a monopoly output $x_{inc}^{K,NE}(t)$.
   2. If entry ensues (E), firms respond producing duopoly output $x_{inc}^{K,E}(t)$ and $x_{ent}^{K,E}(t)$.

- A **separating PBE** can be sustained when priors p are sufficiently high, where:
  - The regulator selects type-dependent fees, and
  - The incumbent chooses $q^H(t)$ and $q^A(t)$ when her costs are high and low, respectively,
    - where $q^A(t_1) > q^L(t_1)$.

Separating equilibrium - Welfare comparisons

1. **Relative to Complete information:**
   - Under complete info.: since entry does not occur, the reg. can induce q^{SO} in both periods.
   - Under incomplete info: the inc. produces a different output in the first and second period, but the reg. selects a single t ($\Longrightarrow$inefficiencies).
     - Hence, $W_{CI}^{L,R} > W_{SE}^{L,R}$.

2. **Relative to ED models in which the regulator is Absent:**
   - When the reg. is absent: overproduction emerging in the SE induces additional pollution.
   - When the reg. is present: Despite not inducing q^{SO}, he ameliorates such overproduction (second best).
     - yielding that $W_{SE}^{L,R} > W_{SE}^{L,NR}$.

Pooling equilibrium

- A **pooling PBE** can be sustained when priors p are low, in which:
    - The regulator selects a type-independent fee $t^{L,NE}$, and
    - Both types of incumbent choose output function $q^L(t)$.

- Hence, the high-cost incumbent "over-produces," while the regulator "over-taxes."
    - They conceal information from the entrant,
    - and entry is deterred.

- Reg. overtaxes when entry-cost savings exceed tax inefficiencies.

1. **Relative to Complete information:**
   - Under complete info: Inefficient regulation, both under CI and PE.
   - Under incomplete info: Since the reg. is willing to overtax, $W_{PE}^{H,R} > W_{CI}^{H,R}$.
     - Hence, if the PE exists, it must be welfare improving.

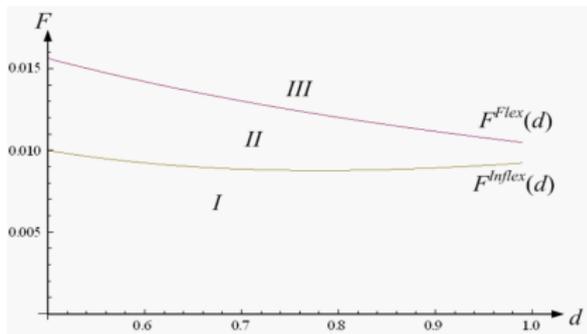2. **Relative to ED models in which the regulator is Absent:**
   - When the reg. is absent: overproduction emerging in the PE induces additional pollution, i.e., $W_{PE}^{H,NR}$ is low.
   - When the reg. is present: Despite not inducing q^{SO}, he ameliorates such overproduction (second best).
     - Hence, $W_{PE}^{H,R} > W_{PE}^{H,NR}$.

- **Flexible regime:** The reg. is less attracted to the PE, since the alternative (SE) yields **optimal** outcomes.
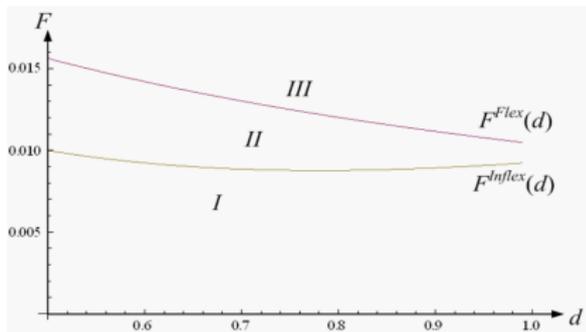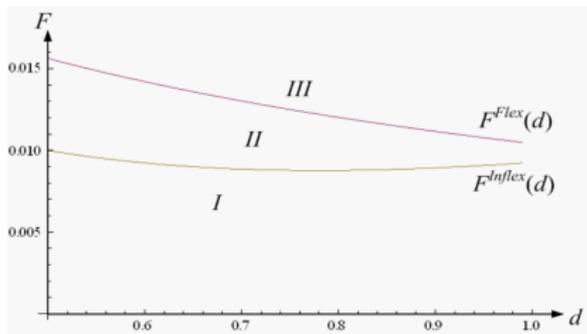
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- **Inflexible regime:** The reg. is more attracted to the PE, since the alternative (SE) yields **suboptimal** outcomes.
  - PE can be supported in regions *III* + *II*.

- **More responsive environmental agencies:**
  - Environmental protection agencies that rapidly adjust to market conditions can *hinder* firms' ED practices.
  - While rigid agencies (e.g., in developing countries) would actually *facilitate* firms' ED.

- **Why not just publicize the incumbent's costs?**
  - Not necessarily optimal for the reg:
    - Playing the PE can entail a larger SW than the CI outcome.
  - Otherwise, SW is larger under CI than PE.

Partially informed regulator

- Our previous analysis assumed that the regulator was perfectly informed.
- What if he isn't?
  - Do firms prefer an informed or uninformed regulator?
  - Espinola-Arredondo and Munoz-Garcia (JRE, 2016)

- Consider that the potential entrant's beliefs are p;
- while the regulator's are p^β, so:
    - when $\beta = 0$, he is certain to face a high-cost inc., $p^0 = 1$;
    - when $\beta = 1$, he is as poorly informed as the entrant, $p^1 = p$;
    - when $\beta \to +\infty$, he is certain to face a low-cost inc. $p^\infty \to 0$.
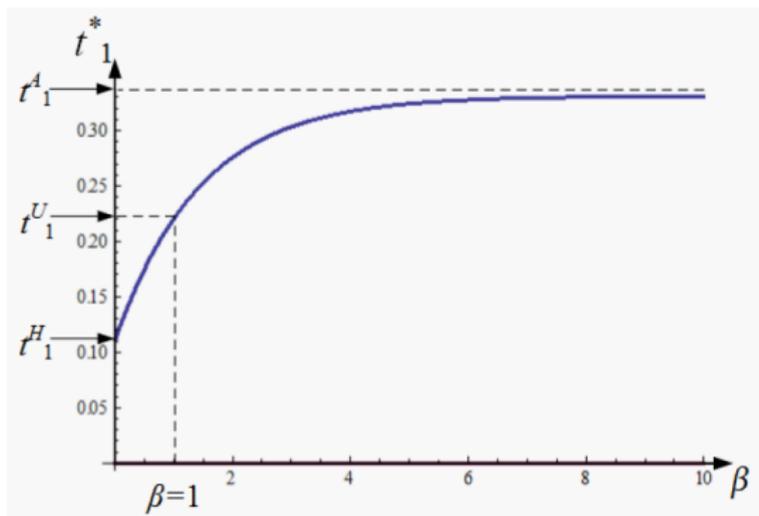
Separating Equilibrium

- The increase in output entails more pollution which the regulator curbs setting a more stringent fee under the SE than under CI.
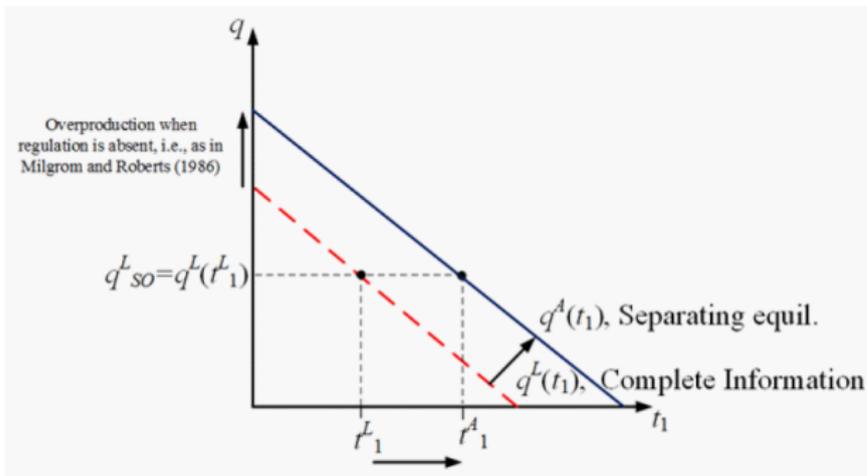
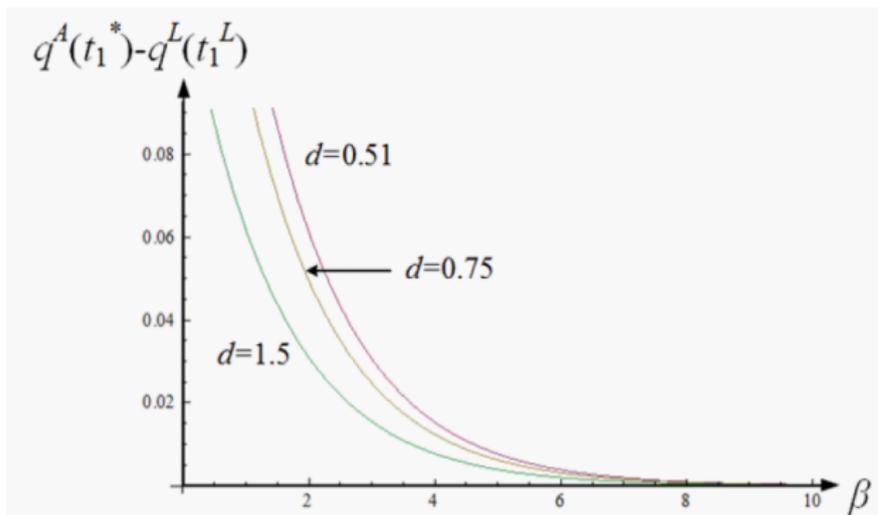SE if the regulator is accurately informed.

Separating equilibrium

- What if the regulator is *not* accurately informed (smaller β)?
  - He sets a *less* stringent fee t_1, closer to t_1^H.

Separating equilibrium

- **Separating effort**, $q^A(t_1^*) - q^L(t_1^L)$:

Separating effort decreases in β and d

- Hence, a less informed regulator (smaller β) gives rise to two effects on profits:
  - A *positive* effect, as he sets less stringent emission fees on the low-cost incumbent.
  - A *negative* effect, as the low-cost firm needs now to increase its separating effort in order to convey its type to the potential entrant.
- **Profits in SE:**
  - Under which conditions the positive effect dominates?
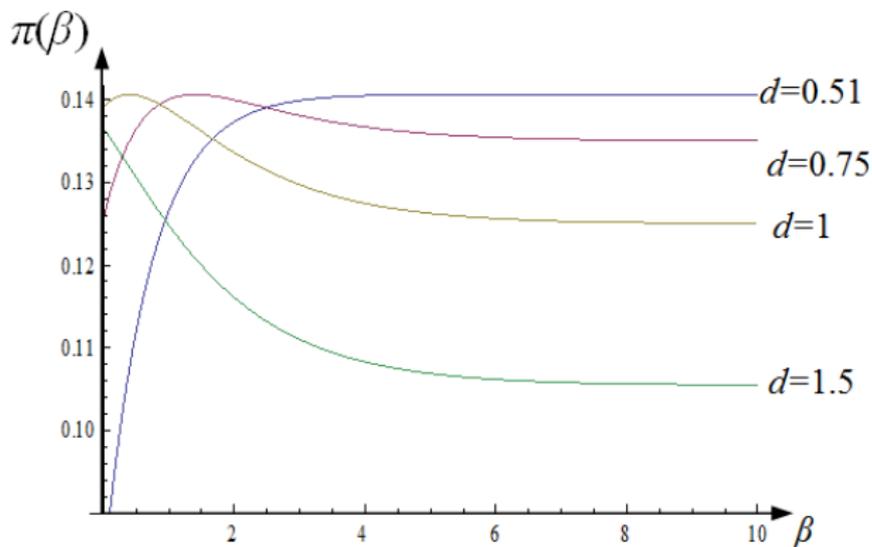
Separating equilibrium

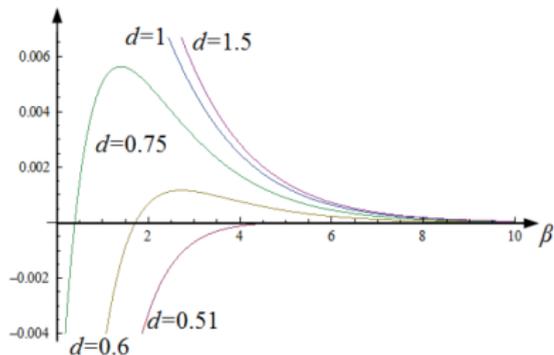- Profits in the SE increase in β iff $\beta < \beta_1$.
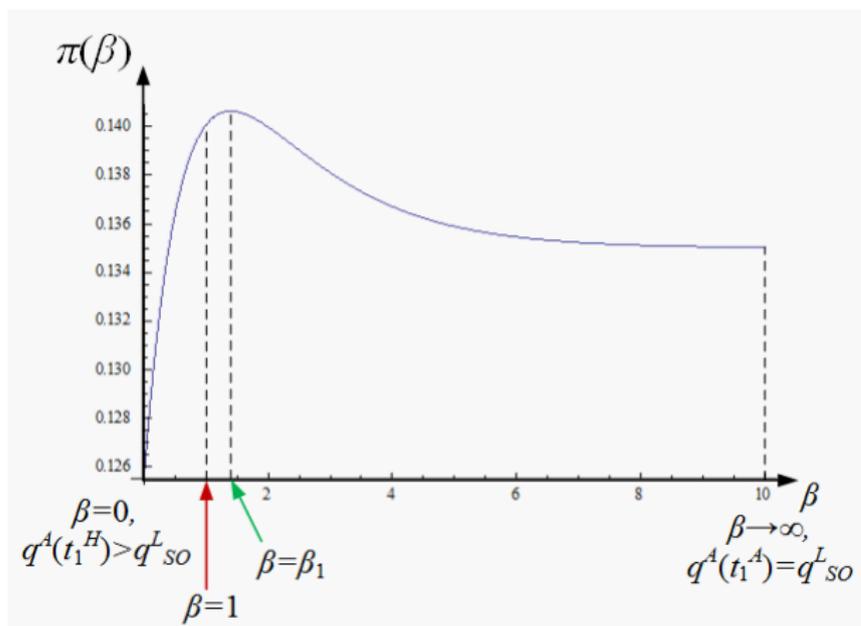
Profits in the SE.

Separating equilibrium

- Sensitivity of profits to environmental damage.

Profits in the SE under different values of d.

Profit difference $\pi_{SE}^{L,R}(\beta) - \pi_{CI}^{L,R}(\beta)$.

- **Intuition:**
  - Under CI, reg. only has a negative effect on profits.
  - Under the SE, regulation also gives rise to a positive effect (ameliorating the firm's separating effort).

- Similar results as in the separating equlibrium.
- An increase in d gives rise to two effects on profits:
    - A *negative effect*, due to more stringent fee; and
    - A *positive effect*, as such strict fee reduces the "mimicking effort" $q_L(t_1^L) - q_H(t_1^H)$.
- As a consequence, profits are larger with regulation when d is high.

- One interesting point:
  - Entry occurs under CI but doesn't under the PE.
  - Then $\pi_{PE}^{H,R} - \pi_{CI}^{H,R}$ can be interpreted as
    - "Incumbent's benefit from deterring entry."
  - We show that such benefit is larger when the regulator is present than absent if...
    - The damage from pollution, d, is sufficiently high (as it facilitates this firm's mimicking effort).

- *Is pollution good for profits?*
    - As pollution becomes more damaging, emission fees are more stringent, which facilitate the inc.'s separating effort.
    - Polluting firms favoring emission fees, e.g., Mining company Rio Tinto, BP, and DuPont.
    - Not-so-polluting firms opposing emission fees, e.g., Freight trains.

- *Firms do not necessarily prefer uninformed regulators:*
  - This is true if firms do not face entry threats.
  - Under entry threats, however, firms' preferences are not monotonic in the regulator's information β.
  - In addition, such preferences depend on the firm's damage from pollution, d.

- *Inefficient firms favoring stringent emission fees:*
  - As described in the PE, inefficient firms can benefit from the presence of the regulator (as he facilitates its mimicking effort).
  - This result holds, in particular, when the damage from pollution is large, and thus emission fees are stringent.
  - More polluting output provides inefficient firms with more incentives to deter entry!

Extensions

- What if we have several incumbents?
  - Use Harrington (1987) or Schultz (1999), but adding regulation as we did above.
- What if production costs are decreasing in the firm's environmental damage d?
- What if the reg. chooses between flexible or inflexible regime?
  - This serves as a third signal to potential entrants.
- What if the incumbent benefits from learning-by-doing in regulation compliance?

Thank you!!!