On Pollution Standard Setting and Compliance Issues

Carmen Arguedas
Universidad Autónoma de Madrid

Developments in Energy Economics
Fundación Ramón Areces
Madrid, 15 February 2018

Outline

1. The Problem
2. Research Questions
3. Enforcing Regulatory Standards in Stock Pollution Problems

1. The problem

The problem

- Pollution standards or limits are very frequent in environmental regulation (air, water, noise, hazardous waste…)

- A pollution standard defines the maximum allowed amount of a certain pollutant that polluting sources can release

- Often classified as command-and-control instruments: polluters are told what they have to do, and it is assumed that they will

- Often regarded as inferior:
  - emissions are not priced (as opposed to carbon taxes)
  - no flexibility is allowed (as opposed to tradable permits)

The problem

Compliance issues are generally ignored

But, in practice, firms may decide to exceed the standards

This may occur if firms' expected costs of violating pollution limits are smaller than firms' compliance costs (Becker ,1968)

Compliance costs: firms' pollution abatement costs

Expected costs of non-compliance: consider the likelihood of being discovered, as well as the possible imposed sanctions.

The problem

In practice, pollution decisions depend not only on the standard, but also on the stringency of the monitoring and enforcement mechanisms, and regulators must account for all these elements

ENFORCEMENT COSTS

- Frequency of inspections (probability) → monitoring costs
- Sanction in case of non-compliance → sanctioning costs

2. Research Questions

Research Questions

1. Appropriate shape of the fines for non-compliance

2. Interaction of interested parties and several layers of government: different information levels, hierarchical issues and coordination problems

3. Standard setting and related enforcement issues in dynamic contexts, both in flow and stock pollution problems

Research Questions

1. Appropriate shape of the fines for non-compliance

Should regulators impose maximum fines as a means of inducing compliance with the lowest possible monitoring effort or should fines be kept low?

MAXIMUM FINES
Becker (JPE, 1968)

versus…

NON-MAXIMUM FINES

Dynamic settings: Harrington (1988), Raymond (1999), Friesen (2003)

Self-reporting: Livernois and McKenna (1999)

Penalty evasion: Kambhu (1999)

Hierarchical governments: Decker (2007)

In practise: sanctions are low (Harrington 1988, Livernois and McKenna 1999) , although compllince rates are still high

An additional factor that justifies the use of limited fines is the presence of administration costs. These depend on:

- the degree of violation, accounting for the costs of court processes, citizens' discomfort with law transgressions, etc. (Polinsky & Shavell 1992, or Stranlund 2007)

- the amount of the fine itself. Firms may lobby the imposition of large fines, and this may result in additional implementation costs (Chen & Lai 2012, or Arguedas, Earnhart & Rousseau 2017.

Arguedas (2008): The appropriate structure of the penalty under non-compliance is highly progressive, while the best possible shape of the fine under compliance is linear. In the presence of administration costs, linear penalties are socially preferred and the optimal standard induces compliance. However, when these costs are not very relevant, non-compliance can then be preferred.

REGARDING THE STRUCTURE/ SHAPE OF THE FINES:

In practise, some environmental regulations offer the possibility of penalty discounts in exchange for polluters' documented evidence of compliance - promoting activities:

- Law 10/93 of Liquid Industrial Waste of Autonomous Community of Madrid
- EPA's Audit Policy: reductions up to 100% of the non-gravity based part of the sanction and 75% of the gravity-based component

Arguedas (2013): Under some circumstances, it is socially desirable that fines depend on the polluter's technology investment effort

2. Hierarchical issues

The pollution standard is generally decided at the national level, while monitoring and enforcement is made by local enforcement agencies.

Differences in both available information and objectives at these two administration levels

National regulators are less informed than local agencies about the characteristics of the polluting agents. This results in the use of uniform standards, and the delegation of the enforcement activity to the local agency

Decker 2007, Arguedas & Rousseau 2015, Arguedas, Earnhart & Rousseau 2017, Makowsky & Stratmann 2009, Garoupa & Klerman 2010, Cheng & Lai 2012, or Ovaere, Proost & Rousseau 2013

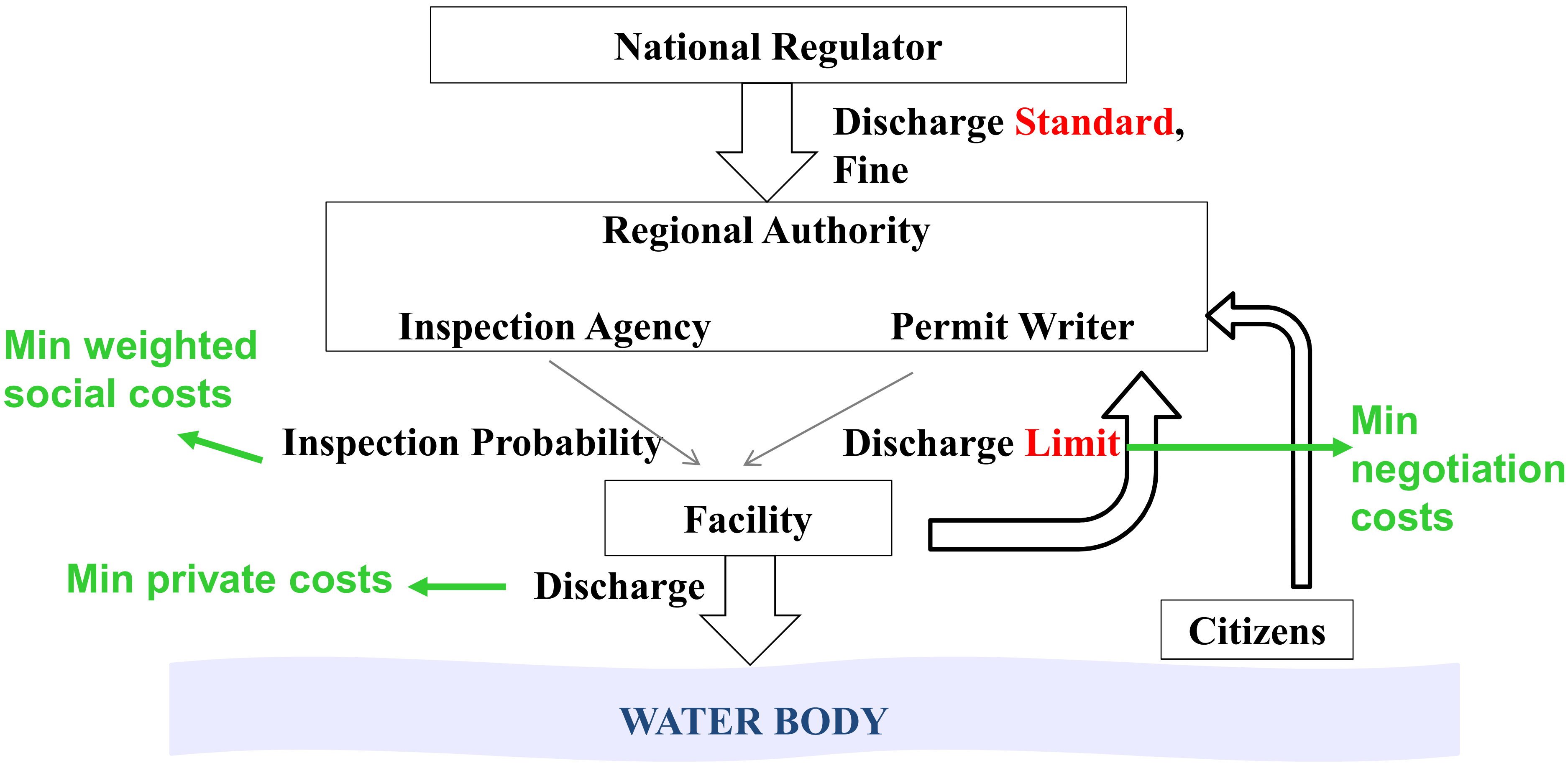
Context

- (1) legal requirements are **constrained** by national or supra-national standards,
- (2) tighter limits can be imposed due to **local ambient conditions**, and
- (3) a **separation** exists **between the authorities** responsible for establishment of the standard, issuance of the effluent limits, and monitoring of compliance with limits.

Examples

- EU Water Framework Directive
- EU waste policy e.g. WEEE Directive
- US Clean Air Act
- US Pipeline and Hazardous Safety Materials Administration

Research Questions



3. Dynamic Aspects

The vast majority of existing works about the setting of regulatory stringency and compliance assume static contexts: Veljanovski 1984, Kambhu 1989, Jones 1989, Jones & Scotchmer 1990, Keeler 1995, Arguedas 2008, 2013, Arguedas&Rousseau 2015, Arguedas, Earnhart&Rousseau

Several works analyze optimal standards in dynamic settings, but they do so assuming perfect compliance: Beavis and Dobb1 1986, Hartl 1992, Conrad 1992, Falk & Mendelsohn 1993, Benford (1998)

Only exceptions that allow for optimal standard setting and non-compliance (over-compliance) are two recent studies of Arguedas, Cabo & Martín-Herrán (2017, 2018), where the cases of flow and accumulative pollutants are respectively studied.

Enforcing Regulatory Standards in Stock Pollution Problems

(with F. Cabo and G. Martin-Herran, U. Valladolid)

Objective: to study the features of optimal pollution limits and enforcement strategies in dynamic contexts.

- Pollution limit: maximum amount of allowed pollution.
- Enforcement strategy:
  - PENALTY if emissions larger than the limit (non-compliance),
  - SUBSIDY if emissions lower than the limit (over-compliance).
- Dynamic aspect: emissions accumulate overtime and environmental damages depend on the stock of pollution

Motivation

- Stakelberg differential game between a regulator and a representative firm.
- The firm uses emissions as the only input in production.
- The regulator can choose:
  - i) Pollution limit.
  - ii) Fine/subsidy per unit of departure of the limit.
  - iii) Both.

  3 scenarios, to be discussed later on.
- Costless/accurate monitoring.
- Stagewise feedback solution:
  - Regulator has an instantaneous advantage at each time
  - Policy controls are set dependent on the pollution stock

The representative firm: follower

- Production of a consumption good

$$Y(E(t)) = \sigma E(t) - \frac{E(t)^2}{2}.$$

Y output, E emissions.

- Pollution stock dynamics

$$\dot{P}(t) = E(t) - \delta P(t), \quad P(0) = p_0.$$

P pollution stock, $\delta > 0$ assimilative capacity of the environment.

- Environmental damage associated with the pollution stock

$$D(P(t)) = d\frac{P^2(t)}{2}, \quad d > 0.$$

Enforcement mechanism

Regulator observes emissions $E(t)$ at no cost.

Given the emission target or pollution limit, $L(t)$:

$$\begin{cases} E(t) > L(t): \text{ non-compliance} \rightarrow \textbf{fine}, \\ E(t) < L(t): \text{ over-compliance} \rightarrow \textbf{subsidy}. \end{cases}$$

Fine/subsidy scheme:

$$G(E(t), L(t), F(t)) = F(t)\left[E(t) - L(t)\right].$$

F is the fine/subsidy per unit of departure from the emission target. Three scenarios:

- Scenario L : L the decision variable; $F = \bar{F}$ fixed overtime.
- Scenario F : F the decision variable; $L = \bar{L}$ fixed overtime.
- Scenario LF: both L and F are policy controls.

The agent (firm): follower

- Maximization problem

$$\max_E \int_0^\infty [\underbrace{\sigma E - \frac{E^2}{2}}_{Y(E)} - \underbrace{F(E-L)}_{G(E,L,F)}]e^{-\rho t}dt$$

$$\text{s.t.: } \dot{P} = E - \delta P, \quad P(0) = p_0.$$

- Best response function

$$\widehat{E}^s(P; \not{L}, F) = \sigma - F + (V^s)'(P),$$

$\widehat{E}^s$ does not depend on L due to the linearity of the fine.

The regulator: Stackelberg leader

- Social welfare:

$$\int_0^\infty [Y(E) - D(P) - H(E - L, F)] e^{-\rho t} dt,$$

where

- Social costs for non-compliance depend on:
  - the degree of non-compliance/over-compliance, $\beta \frac{(E-L)^2}{2}$,
  - the severity of the fine/generosity of the subsidy, $\xi \frac{F^2}{2}$,

The regulator: Stackelberg leader

- Social welfare:

$$\int_0^{\infty} \left[Y(E) - D(P) - H(E-L,F) \right] e^{-\rho t} dt,$$

where

- Social costs for non-compliance depend on:
  - the degree of non-compliance/over-compliance, $\beta \frac{(E-L)^2}{2}$,
  - the severity of the fine/generosity of the subsidy, $\xi \frac{F^2}{2}$,

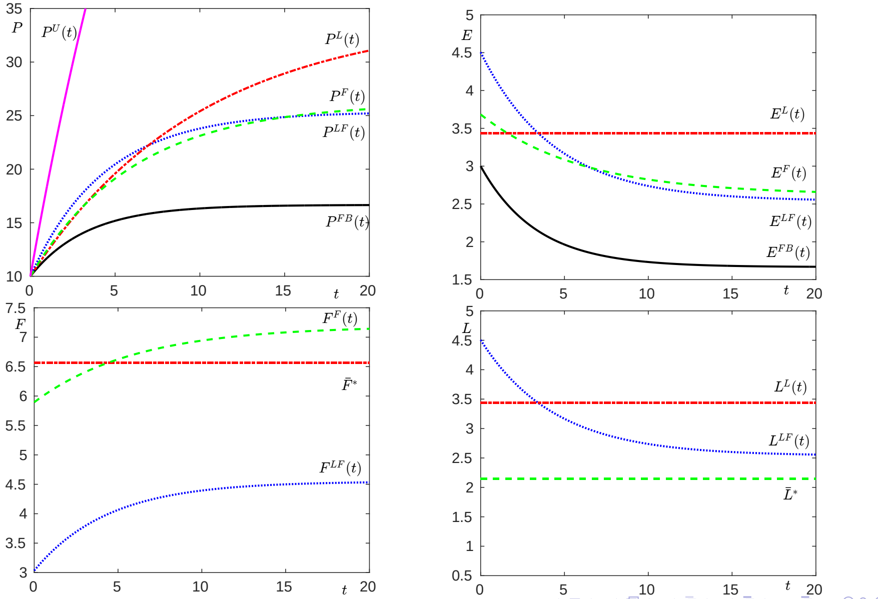
The regulator: Stackelberg leader

Stackelberg leader: knowing $\widehat{E}^s(P;F)$ maximizes:

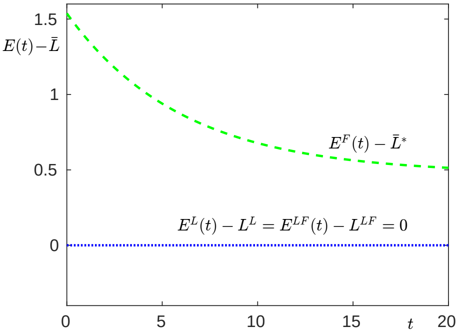
$$\int_0^\infty \left[\underbrace{\sigma \widehat{E}^s(P;F) - \frac{[\widehat{E}^s(P;F)]^2}{2}}_{Y(\widehat{E}^s(P;F))} - \underbrace{d\frac{P^2}{2}}_{D(P)} - \underbrace{\left[\beta \frac{[\widehat{E}^s(P;F) - L]^2}{2} + \xi \frac{F^2}{2} \right]}_{H(\widehat{E}^s(P;F)-L,F)} \right] e^{-\rho t} dt,$$

s.t.: $\dot{P} = \widehat{E}(P;F) - \delta P, \quad P(0) = p_0.$

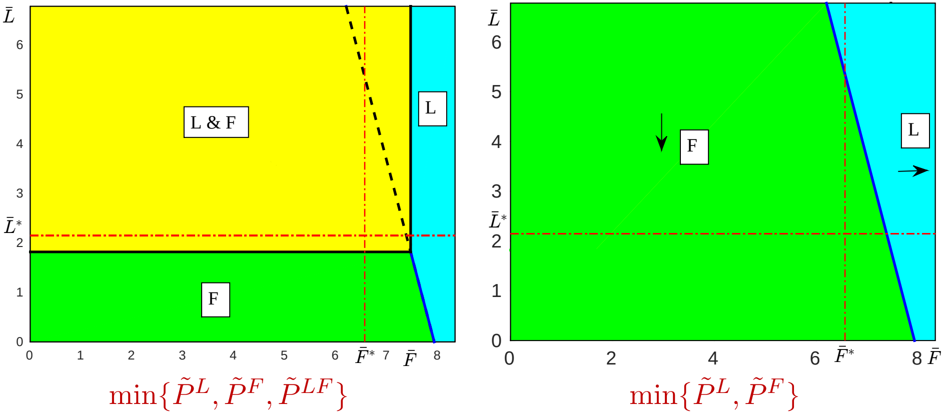
Preliminary results (I). Time paths: P, E, F, L



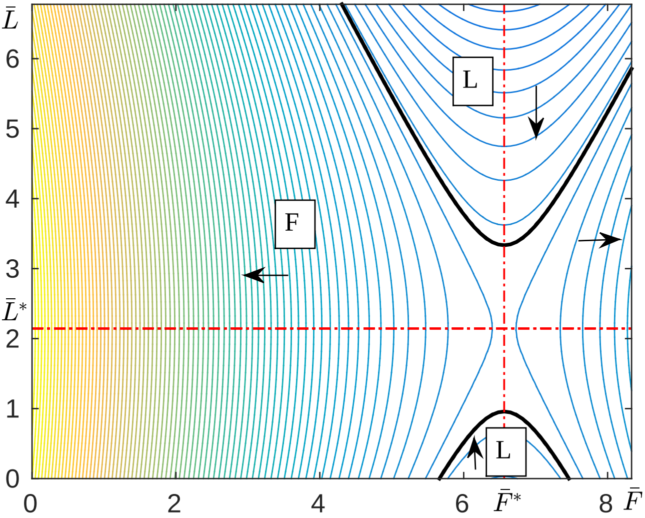
Preliminary results (II). Time paths: $E - L$



Preliminary results (III). long-run pollution stock.

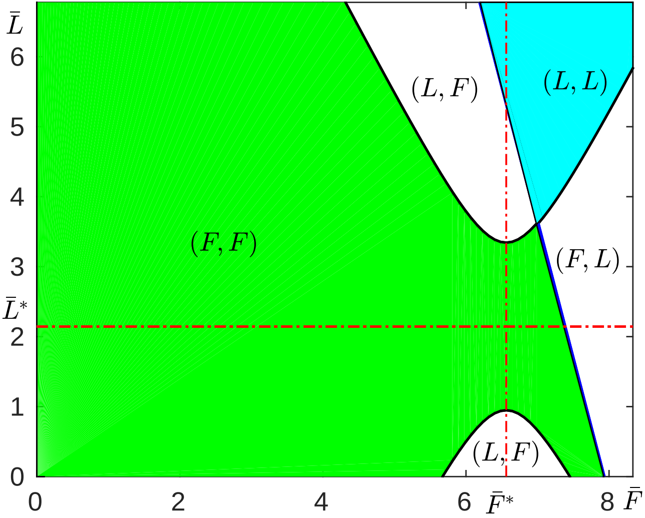


Preliminary results (IV). Social welfare.

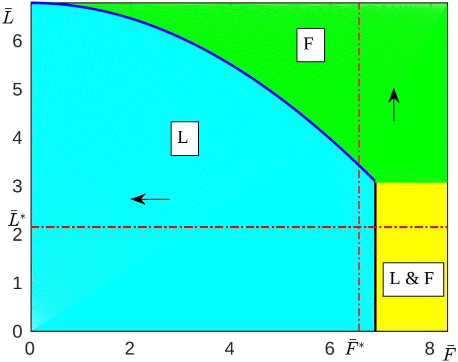


Level curves for $W^F(p_0) - W^L(p_0)$

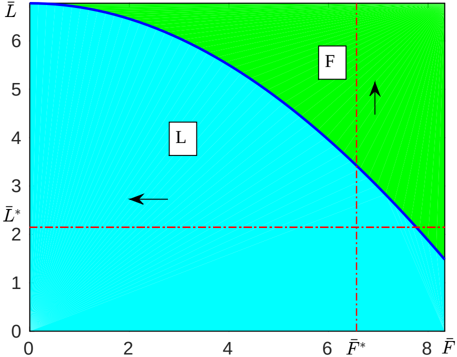
Preliminary results (V). Social welfare vs. pollution stock.



Preliminary results (VI). Firm's profits.



$$\max\{\tilde{V}^L(p_0), \tilde{V}^F(p_0), \tilde{V}^{LF}(p_0)\}$$



$$\max\{\tilde{V}^L(p_0), \tilde{V}^F(p_0)\}$$

Preliminary results: Summary.

- All policy scenarios evolve between laissez-faire and first best.
- F: increases with the pollution stock.
- L: decreases with the pollution stock (scenario LF)/ remains constant (scenario L).
- Scenario LF mostly preferred both in environmental and social welfare terms.
- With only one policy instrument:
  - Scenario F mostly preferred over scenario L both in environmental and social welfare terms.
  - However scenario F induces non-compliance/ over-compliance.
- Scenario L mostly preferred by the firm.

A non-linear fine. The agent (firm): follower

- Maximization problem

$$\max_E \int_0^\infty \{\underbrace{\sigma E - \frac{E^2}{2}}_{Y(E)} - \underbrace{\left[F(E-L) + \theta\frac{(E-L)^2}{2}\right]}_{G(E,L,F)}\}e^{-\rho t}dt$$

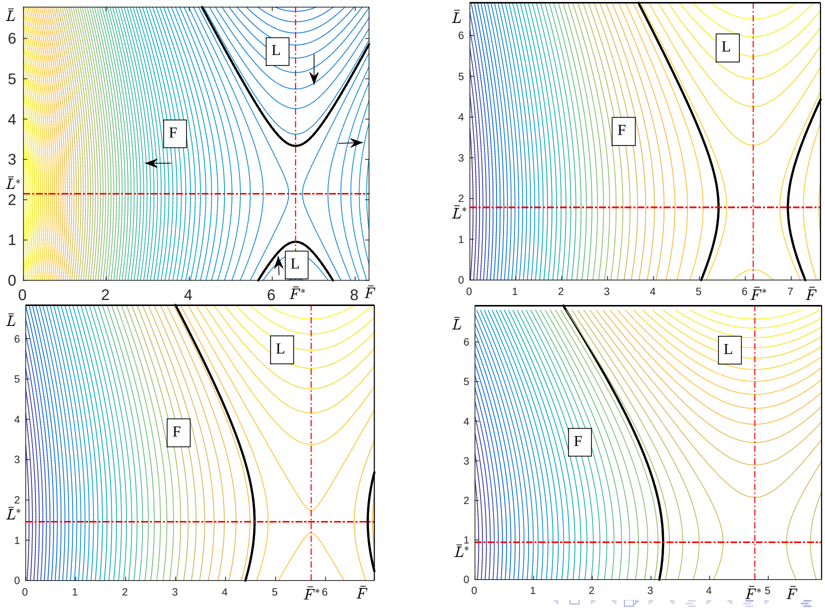
s.t.: $\dot{P} = E - \delta P, \quad P(0) = p_0.$

- Best response function

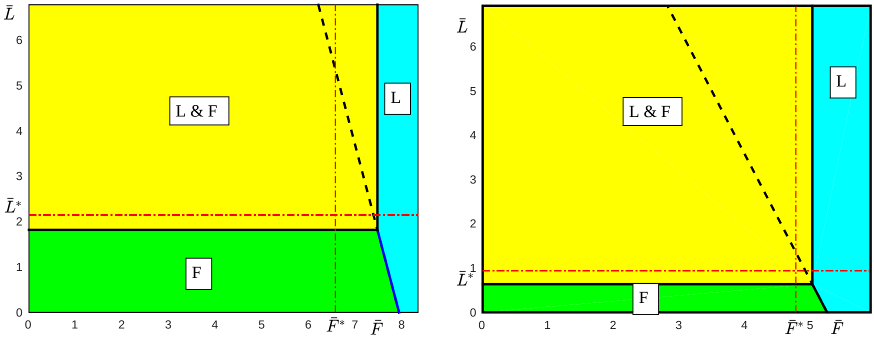
$$\widehat{E}^s(P; L, F) = \frac{\sigma - F - \theta L + (V^s)'(P)}{1+\theta},$$

$\widehat{E}^s$ does depend on F and L

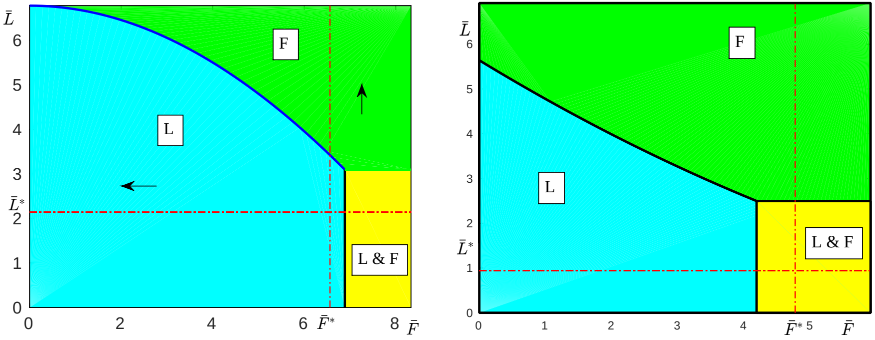
LQ: Comparison of social welfares: $\theta = 0, 0.1, 0.2$ y 0.4



LQ: Comparison of long-run pollution stocks: $\theta = 0$ y 0.4



LQ: Comparison of firm's profits: $\theta = 0$ y 0.4



Sensitivity analysis (I)

Sensitivity of our results w.r.t. changes in the parameter values:

- d: effect of pollution stock on environmental damages.
- σ: productivity of emissions.
- β: social costs related to non-compliance/over-compliance.
- ξ: social costs related to the firm's lobbying for the level of the fine.
- p_0: initial pollution stock.

Two dimensions:

- Effect of parameters on the main variables.
- Effect of parameters on regions delimiting best scenario from the viewpoint of: { i) long-run pollution stock, ii) social welfare.

Research agenda

1. Imperfect monitoring
2. Coordination problems in dynamic contexts
3. Heterogeneous pollutants

Thank you!

carmen.arguedas@uam.es