June, 2009

Title?

Choosing Policy Instruments to Control Pollution under Costly Monitoring, Sanctioning Costs and Incomplete Information

**Marcelo F. Caffera**

Departamento de Economía

Universidad de Montevideo

**Carlos A. Chávez**[[1]](#footnote-2)\*

Departamento de Economía

Universidad de Concepción

Marcelo: la propuesta que sigue tiene como intención también ordenarnos en cuanto a intentar enfatizar/mostrar lo que en màs nuevo y novedoso con respecto a la literatura previa: Arguedas (2008), John (2007) y Chàvez, Villena, Stranlund (2009)

#### Abstract: We study the optimality of inducing compliance under a system of emissions standards. Under the assumption of incomplete information, our analysis considers not only that monitoring compliance is costly, but also that imposing sanctions demand resources from the society. We also examine the optimal allocation of abatement responsabilities in this context. We found that under specific circumstances it might be cost-effective to induce perfect expected compliane of some firms while leaving others to violate the standard. In addition, we found that the distribution of abatement responsabilities that minimize aggregate program costs must consider expected abatement costs, expected monitoing costs, and expected sanctioning costs, which in general will result in a distribution of emission control that differ from the distribution of emissions generated by a competitive transferable emissions permit system. Then, considering the total program costs of an emissions standard system (abatement, monitoring, and sanctioning) we characterize the optimal design of a command-and- control rgulation. We found that it should induce expected perfect compliance by every firm. Further, we compare the cost of a well designed system of firm specific emissions standards wit the costs of a well enforced perfectly competitive transferable emissions permit system in the context of incomplete information.

***JEL Classification*:** *L51, Q28 , K32, K42*.

***Keywords*:** Environmental policy, cost-effectiveness, enforcement costs, sanctioning costos, incomplete information.

Title?

Choosing Policy Instruments to Control Pollution under Costly Monitoring, Sanctioning Costs and Incomplete Information

**1. Introduction**

-Motivation

-What do we do?

-We study the optimality of inducing compliance under a system of emissions standards. Under the assumption of incomplete information, our analysis considers not only that monitoring compliance is costly, but also that imposing sanctions demand resources from the society.

-We also examine the optimal allocation of abatement among firms in this context.

-Considering the total program costs of an emissions standard system (abatement, monitoring, and sanctioning) we characterize the optimal design of a command-and- control regulation.

- Further, we compare the cost of a well designed system of firm specific emissions standards wit the costs of a well enforced perfectly competitive transferable emissions permit system in the context of incomplete information.

-What do we obtain?

-We found that under specific circumstances it might be cost-effective to induce perfect expected compliance of some firms while leaving others to violate the standard.

-In addition, we found that the distribution of abatement responsabilities that minimize aggregate program costs must consider expected abatement costs, expected monitoring costs, and expected sanctioning costs, which in general will result in a distribution of emission control that differ from the distribution of emissions generated by a competitive transferable emissions permit system.

- We found that a regulator should induce expected perfect compliance by every firm.

-We found that a transferable emissions permit system not always is preferable, but information problems is the main reason to implement them. We should built this argument better! It is among the most important, as I see our progess.

-Relate motivation and findings to the existing literature.

-Stranlund (2007) has already shown how a transferable emissions permit system should be designed.

-Malik (1992), Hahn and Axtell (1995), Chávez, Stranlund, and Villena (2009) have considered the optimal design of a system of emissions standards. Their assumptions differ in terms of information available to the regulator. None of them has considered sanctioning costs. Arguedas (2008) is the first one to examine the optimal design of an emission standard system with monitoring costs and sanctioning costs. She assumed pefect information and consider just one firm.

-Contrast with Arguedas (2008), we model a set of heterogenous firms, instead of just one. This, introduce heterogeneity into the analysis not only in terms of abatement costs, but also along with monitoring costs, and the cost of imposing sanctions to violators.

**2. A Model of Compliance Under a System of Firm Specific Emissions Standards**

-The purpose of this section is to present a conceptual model of the individual firm’s behaviour and choices under a command and control regulation. The model we present follows previous work by Malik (1992), Heyes (2000), and Arguedas (2008).

*The polluter firm and its regulation*

-To analyze the individual firm’s compliance behaviour, we consider a risk-neutral firm under an emissions standard system, along with a fixed number of other heterogeneous firms.

-The firm’s abatement cost function is *c*(*e*, *θ*), which is strictly decreasing and convex in the firm’s emissions *e* [*ce* (*e*, *θ*) < 0 and *cee* (*e*, *θ*) > 0]. A firm is distinguished from others by the shift parameter *θ*.[[2]](#footnote-3) Should we use sub-index for this derivatives?

-We assume that both the firm’s abatement costs and its marginal abatement costs are increasing in *θ*, that is, *cθ*(*e*, *θ*) > 0 and *ceθ* (*e*, *θ*) > 0.

-We index firms by *i* anddenote the total number of firms as *n* (whenever possible, we avoid the use of a specific firm index for simplicity)*.* The environmental target is a fixed aggregate level of emissions *E*, exogenously determined by the regulatory authority.

-We consider the case of a command and control environmental policy in which each firm faces an emissions standard *s*. Under this policy the regulator defines for each firm the maximum level of emissions.

-The emissions standards for all firms satisfy .

-An emissions violation *v* occurs when the firm’s emissions exceed the emissions standard: *vi* = *ei* – *si* > 0. The firm is compliant otherwise.

*Enforcement*

-As for enforcement, the firm faces a random probability of being audited *π.*

-An audit provides the regulator perfect information about firms’ compliance status. If the firm is audited and found in violation, a penalty *f* (*v*) is imposed. The penalty is assumed to be zero for a zero violation, but the marginal penalty for a zero violation is greater than zero [*f* (0) = 0, *f* ′(0) > 0]. For a positive violation, the penalty increases at an increasing rate [*f* ′′ (*v*) > 0]. Should we introduce as early as here the discusion about different penalty structures?

-In our analysis, perfect compliance is a possible outcome, then we shall assume –*cei*(*si*,*θi*) ≤ *f* ′(0); that is, the firm’s marginal abatement cost evaluated at the standard is not greater than the marginal penalty for a slight violation.[[3]](#footnote-4)

-Under an emissions standard, a firm *i* chooses the level of emissions to minimize total expected compliance cost, which consists of its abatement costs plus the expected penalty. Thus, a firm’s problem is to choose the level of emissions to solve

*min* *ci*(*ei*, *θi* ) + *πi* *f*(*ei* – *si*)

*s*.*t*. *ei* – *si* ≥ 0.

The Lagrange equation for the problem in (1) is given by, which gives the set of necessary Kuhn-Tucker conditions:





*Firm’s Choices*

-From the regulator perspective, the firm’s emissions choice is given by:





-A firm will be compliant, in expected terms, whenever it chooses a level of emissions consistent with *E*(–*cei*(*si*,*θi*)) = ≤ *πf* ′(0), (Malik (1992), Heyes (2000) derive this conditions without explicitly consideration of incomplete information).

-Firm’s compliance choice requires the expected marginal penalty to be no lower than the marginal abatement cost associated with an emissions level equivalent to the emissions standard.

-Please, note that the marginal abatement costs at the level of the standard can vary among firms, not only because they face a different standard, but also because of the firm’s specific, possibly imperfectly observable characteristics for a regulatory authority.

**3. Enforcement Strategies, Enforcement Costs, and the Optimal Level of Compliance**

**-** If the regulator wants to ensure expected perfect compliance the following restriction must hold

 

**-** The analysis about individual compliance behaviour suggests that cost-effective enforcement of emissions standards should involve targeted monitoring. Specifically, minimum required monitoring to induce compliance by firm *i* is given by:



-Monitoring Costs, Sanctioning Costs, and Program Costs*.* Aggregate program costs (*PC*) includes aggregate abatement costs (*A*), monitoring costs (*M*), and sanctioning costs (*S*). Monitoring costs depend upon the effort (audit probability for each firm) and the cost of conducting an audit, which we denote by *μi*. We shall notice that: (i) monitoring costs can vary across firms for several reason (firm location, number of discharges points, etc.) (CITE Stranlund, et al (2009)??-JEEM, Heyes??) , (ii) the level of the expected monitoring costs depends on the enforcers’ available information (Chávez et al (2009).

-Sanctioning costs may include costly warning activities, costly litigation because of firms’ challenging the regulator, and even costly imposition of sanctions once a violation is detected and perhaps going trough a court procedure (CITE LITERATURE ON THIS??, Peter Just??, Kahmbur??). To our knowledge, in the enforcement of environmental regulation literature, only Stranlund (2007) has considered costly collection of sanctions in the context of a transferable emissions permit system; Stranlund et al. (2009) assume that imposing sanctions in the context of emissions taxes is costly. Furthermore, sanctioning costs have been considered in the context of the enforcement of emission standards in Malik (1993) and more recently Arguedas (2008) SOMETHING ELSE, WE NEED TO CHECK ON THIS. By following the existing related literature we model expected sanctioning costs from firm *i* as the result of the product of the monetary cost per unit of collected penalty, which we donote *βi* and the expected level of penalty from that firm. The aggregate sanctioning cost is obtained by adding on the set of firms. We notice that expected sanctioning costs can vary among firms not only because of differences in the expected penalty, but also, because of variation in the monetary cost per unit of penalty. For example, firms might differ in terms of how much effort they spent challenging the regulator, WE NEED TO COMPLETE HERE FROM THE NOTES WITH OUR DISCUSSIONS

WE ALSO NEED TO DEFINE IF WE MODEL IN GENERAL WITH VARIATION BETWEN FIRMS IN AUDITING COSTS AND SANCTIONING COSTS

-We write an expression for total expected program costs under an emissions standards system:

,

-Where 

- 

-

-Then , we write



**4. The Expected Cost-Minimizing Design of Emissions Standards**

**5. The Costs of Optimally Designed Command and Control and Transferable Emissions Permit System (or Choosing Policy Instruments....)**

**6. Conclusion**

*References*

Arguedas, Carmen. (2008). ·To Comply or Not to Comply? Pollution Standard Setting Under Costly Monitoring and Sanctioning”, *Environmental and Resource Economics* 41: 155-168.

Blackman, Allen. (2009). “Colombia’s Discharge Fee Program: Incentives for Polluters or Regulators?”, *Journal of Environmental Management* 90 (1): 101-119.

Bohm, Peter and Clifford S. Russell. (1985). “Comparative Analysis of Alternative Policy Instruments”, in A. V. Kneese & J. L. Sweeney, eds., *Handbook of Natural Resource and Energy Economics*, Elsevier

Burtraw, Dallas. (1996). “The SO2 Emissions Trading Program: Cost Savings without Allowance Trades”, *Contemporary Economic Policy* 14(2): 79-94.

Burtraw, Dallas. (1999). “Cost savings, market performance and economic benefits of the US Acid Rain Program”, in S. Sorrell and J. Skea, eds., *Pollution for Sale: Emissions Trading and Joint Implementation*, Edward Elgar Publishing Limited.

Chávez, Carlos, Mauricio Villena, and John Stranlund. (2009). “The Choice of Policy Instruments to Control Pollution Under Costly Enforcement and Incomplete Information”, forthcoming in *Journal of Applied Economics*.

Cohen, Mark. (1999). “Monitoring and Enforcement of Environmental Policy”, in Henk Folmer and Tom Tietemberg, eds., *International Yearbook of Environmental and Resource Economics* 1999/2000, Edward Elgar Publishing.

Garvie, Devon and Andrew Keeler. (1994). “Incomplete Enforcement with Endogenous Regulatory Choice”, *Journal of Public Economics* 55: 141-162.

Hahn, Robert and Robert Axtell. (1995). “Reevaluating the Relationship between Transferable Property Rights and Command and Control Regulations”, *Journal of Regulatory Economics* 8: 125-148.

Heyes, Anthony. (2000). “Implementing Environmental Regulation: Enforcement and Compliance”, *Journal of Regulatory Economics* 17(2): 107-129.

Malik, Arun. (1992). “Enforcement Cost and the Choice of Policy Instruments for Controlling Pollution”, *Economic Inquiry* XXX: 714-721.

Malik, Arun. (1990). “Markets for Pollution Control when Firms are Noncompliant”, *Journal of Environmental Economics and Management* 18: 97-106.

Montero, Juan Pablo, José Miguel Sánchez, and Ricardo Katz. (2002). “A Market-Based Environmental Policy Experiment in Chile”, *Journal of Law and Economics* 45: 267-287.

Montero, Juan Pablo, José Miguel Sánchez, and Ricardo Katz. (2001). “Análisis del Mercado de Emisiones de Material Particulado en Santiago”, *Estudios Públicos* 81: 177-203.

Palacios, Milagros and Carlos Chávez. (2005). “Determinants of Compliance in the Emissions Compensation Program in Santiago, Chile”, *Environment and Development Economics* 10(4): 453-483.

Palacios, Milagros and Carlos Chávez. (2002). “Programa de Compensación de Emisiones: Evaluación de su Diseño de Fiscalización y Cumplimiento”, *Estudios Públicos* 88: 97-126.

Russell, Clifford S. and Philip T. Powell. (1996). “Choosing Environmental Policy Tools: Theoretical Cautions and Practical Considerations”, in Marie L. Livingston, ed, *Environmental Policy for Economies in Transition: Lessons Learned and Future Directions*, Proceedings of the Resource Policy Consortium Symposium, Washington, D.C.

Stranlund, John K. (2007). “The Regulatory Choice of Noncompliance in Emissions Trading Programs”, *Environmental and Resource Economics* 38(1), 99-117.

Stranlund, John and Kanwalroop K. Dhanda. (1999). “Endogenous Monitoring and Enforcement of a Transferable Emissions Permit System”, *Journal of Environmental Economics and Management* 38(3): 267-282.

1. \* Send correspondence to Marcelo Caffera, Departamento de Economía, Universidad de Montevideo, Direcciòn postal , Montevideo, Uruguay. Phone: (XX-ZZ) XXXXXX, Fax: XXXXXX, E-mail: [marcaffera@um.edu.uy](mailto:marcaffera@um.edu.uy). Carlos Chávez, Departamento de Economía, Universidad de Concepción, Concepción, Chile, E-mail: cchavez[@udec.cl](mailto:cchavez@udec.cl). We gratefully acknowledge financial support provided by Agencia Nacional de Investigación e Innovación (ANII)-Fondo Clemente Estable-Uruguay, under Project ANII FCE 2007-351. [↑](#footnote-ref-2)
2. Firms’ abatement costs can vary for many reasons, including differences in production and emissions control technologies, input and output prices, and specific factors related to the corresponding industrial sector. [↑](#footnote-ref-3)
3. An alternative penalty function could be a two part penalty, i.e. *F*(*v*) = *Fo* + *f* (*v*), where *Fo* is a fixed fee. Malik (1992), does not consider such type of penalty structure as well as most of the literature (right?). Arguedas (2008) has already shown that, for the case of one regulated firm, is not optimal to have a fixed penalty component when inducing compliance with an emissions standard. [↑](#footnote-ref-4)