

Franckx, Laurent

Working Paper

Environmental enforcement with endogenous ambient monitoring

Nota di Lavoro, No. 88.2002

Provided in Cooperation with:

Fondazione Eni Enrico Mattei (FEEM)

Suggested Citation: Franckx, Laurent (2002) : Environmental enforcement with endogenous ambient monitoring, Nota di Lavoro, No. 88.2002, Fondazione Eni Enrico Mattei (FEEM), Milano

This Version is available at:

<https://hdl.handle.net/10419/119695>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

Fondazione Eni Enrico Mattei

Environmental Enforcement with Endogenous Ambient Monitoring

Laurent Franckx

NOTA DI LAVORO 88.2002

OCTOBER 2002

ETA – Economic Theory and Applications

Laurent Franckx, *Royal Military Academy, Economics and Management, Brussels*

This paper can be downloaded without charge at:

The Fondazione Eni Enrico Mattei Note di Lavoro Series Index:

http://www.feem.it/web/activ/_wp.html

Social Science Research Network Electronic Paper Collection:

http://papers.ssrn.com/abstract_id=XXXXXX

The opinions expressed in this paper do not necessarily reflect the position of
Fondazione Eni Enrico Mattei

Environmental Enforcement with Endogenous Ambient Monitoring

Summary

We consider an inspection game between “ n ” polluting firms and an environmental enforcement agency. If the cost of monitoring ambient pollution is low enough, the optimal inspection policy consists in imposing the maximal possible fine, and mixing between observing ambient pollution and not conducting any inspection at all. However, with stringent upper limits on the fine, the agency mixes between observing ambient pollution and inspecting all firms. The observation of ambient pollution is always followed by sequentially rational firm inspections. Comparisons with Franckx (2002a,2002b) show that commitment power has a very strong impact on the value of prior information.

Keywords: Environmental enforcement, ambient inspections, commitment

JEL: K42, Q20

This paper has been presented at the Workshop on “Game Practice and the Environment”, jointly organised by Università del Piemonte Orientale and Fondazione Eni Enrico Mattei, Alessandria, April 12-13, 2002.

Address for correspondence:

Laurent Franckx
Royal Military Academy
Economics and Management
Renaissancelaan 30
1000 Brussels
Belgium
Phone: 0032(0)2 737.64.57
Fax: 0032(0)2 737.65.12
E-mail: laurent.franckx@egeb.rma.ac.be

1 Introduction

Several authors have proposed to use ambient-based policies to regulate non-point source pollution - see for instance the survey in Xepapadeas (1999). The basic idea, first proposed by Segerson (1988), is that polluters would pay *full* marginal damages per unit deviation if ambient pollution concentration exceeds a given target, rather than their *contribution* to marginal damages. Thus, the tax basis is not individual emissions of the polluter, but observed ambient pollution. Others (see, for instance, Shortle and Abler (1997)) have however pointed out some problems with the feasibility of the proposed schemes.

A slightly different approach would be to compare a setting where the enforcement agency observes ambient pollution to guide its *enforcement* efforts with a setting where such ambient inspections do not take place. To the best of our knowledge, Franckx (2002a) and Franckx (2002b) are the first contributions using this approach.

A key question raised in these papers is how the only parameter that is determined by public authorities (the fine for noncompliance) affects the desirability of ambient monitoring. The answer is that the role of the fine depends crucially on the commitment power of the enforcement agency. In Franckx (2002b), it is assumed that the enforcement agency can commit both to the probability of firm-level inspections and to ambient monitoring. It is then shown that for high fines, the agency will prefer not to conduct ambient inspections. In Franckx (2002a), the agency can commit to ambient monitoring, but not to the probability of firm-level inspections. In this context, higher values of the fine *increase* the desirability of ambient inspections from the inspection agency's point of view.

In this paper, we drop the assumption that the agency can commit to ambient monitoring¹ and we endogenize the decision to hold ambient inspections. Therefore, we use the perfect Bayesian equilibrium solution concept (PBE): each player's strategy must be a best response to the others' equilibrium strategy (the strategies must thus constitute a Nash equilibrium (NE)). Moreover, if the agency conducts ambient inspections, it must update its *a priori* beliefs with respect to the firms' strategies according to Bayes' rule wherever possible. We show that this slight change in the institutional context again *completely* changes the role played by the fines for noncompliance.

Besides this change in the setting of the model, we also offer two technical generalizations: Franckx (2002a) and Franckx (2002b) use a very specific and controversial objective function for the inspection agency, and assume that the agency can put inspected noncompliant firms in compliance. We show that changing these assumptions does not affect the main results at all.

Finally, we extend the two-firm model considered in Franckx (2002a) to an arbitrary number of firms.

The technical and notational assumptions of this paper are the following.

We consider n polluting firms, who have no interaction, neither in the input, nor in the output market. They can choose between two levels of abatement expenditure, α and 0. If a firm spends α , it is in compliance. We assume a one-

to-one relationship between emissions and the chosen abatement technology, so that the environmental damage due to the choice of a particular abatement technology only depends on that technology; we exclude any stochastic influences.

We assume that, for the agency, the cost of the compliant abatement technology is D_c ; the cost of noncompliance will be represented as D_{nc} . Note that D_{nc} and D_c can be given a wide range of interpretations. For instance, if the agency maximizes social welfare, D_{nc} and D_c are the monetary value of environmental damages net of private compliance costs. Or, alternatively, for an agency that narrowly focuses on environmental effects, D_{nc} and D_c are just the monetary value of environmental damages. We assume that $D_{nc} > D_c$: otherwise, the agency would have no reason to pursue compliance.

Ambient environmental inspections costs a per time period. Inspecting the firm costs b . If a firm is inspected and is found in noncompliance it will have to pay a fine $\Psi > 0$ with certainty. Except in Section 3.2.5, we assume that this fine is set by a higher authority in government, say the legislator, and is thus exogenous in this model.

We also assume that the agency derives *some* benefit Δ from inspecting a noncompliant firm. For instance, the career perspectives of the agency's staff may depend on the number of detected noncompliant firms, or the staff may derive some moral satisfaction from fining noncompliant firms. Alternatively, the agency might have the authority to put a noncompliant in compliance during an inspection; Δ then represents the environmental benefit (net of private compliance costs) of inspecting a noncompliant firm. In order to allow for this latter interpretation, we shall from now on assume that a firm that is found in noncompliance has to incur a fraction γ of the costs of purchasing the new abatement technology, where $\gamma \in \{0, 1\}$. However, we shall assume no redistribution of fines to the agency, so that Δ is completely independent from Ψ .

Finally, we shall assume that $\Delta < D_{nc} - D_c$. This condition means that, even with zero inspection costs, the agency derives larger benefits from spontaneous compliance than from putting noncompliant firms in compliance. This assumption is not obvious, but will only turn out to be crucial in the proof of Lemma 15.

We only consider equilibria where the firms all play the same strategy. In the specific case of two polluting firms, Franckx (2002a) has shown the existence of equilibria where the firms play different strategies. The assumption of symmetry in the firms' strategies is thus only introduced to keep the analysis tractable, but excludes possibly interesting asymmetric behavior.

All parameters of the model are common knowledge.

The structure of the paper is as follows. In Section 2, we determine the agency's best response for any given probability of compliance. Next, we determine the firms' best response to the agency's and the other firms' strategies (Section 3). We show then that for all possible relative parameter values, we have a unique PBE. In Section 4, we show that the conclusions obtained in Franckx (2002a) and Franckx (2002b) do not depend, nor on the agency's objective function, neither on the assumption that the agency can put noncompliant firms in compliance. Thus, the agency's commitment power is the only critical

factor in the outcome of the game. Section 5 summarizes the main findings.

2 The agency's best response

Suppose that the firms comply with probability p_α .

What is then the agency's optimal reaction?

First note that the inspection agency will certainly not undertake any type of inspections if $b > \Delta$: if the cost of inspecting one firm is higher than the benefit of bringing one non-compliant firm into compliance, it is optimal for the agency never to inspect. Therefore, we shall not consider $b > \Delta$ again.

Proposition 1 *If $b > \Delta$, the agency does not undertake any inspections (neither ambient inspections nor firm inspections). The firms never comply.*

In what follows, we shall also ignore the limiting case $b = \Delta$. The probability that these two technical parameters are equal to each other is zero, and the relevance of this case can thus be doubted. Moreover, allowing this to happen would lead to indeterminacies.

As the specific case of two polluting firms has been treated in detail in Franckx (2002a), we also assume from now on that $n > 2$.

In Section 2.1, we derive the agency's cost function with ambient inspections, assuming that it conducts sequentially rational strategies. In Section 2.2, we determine the agency's cost function without ambient inspections. In Section 2.3, we determine the agency's best response for a given probability of compliance. The mathematical details of the arguments used in Section 2.3 are given in Appendix A.

2.1 With ambient inspections

If the agency conducts ambient inspections, the timing of the game is:

- The firms simultaneously choose their abatement technology, without knowing whether the agency observes ambient pollution or not
- The enforcement agency observes ambient levels
- The enforcement agency chooses the firms it will inspect

We assume that the agency perfectly observes ambient levels and can thus correctly infer how many firms comply: it faces two singleton (all firms comply, no firm complies) and $n - 1$ non-singleton information sets.

In a perfect Bayesian equilibrium (PBE), the agency's strategy at each information set must be sequentially rational.

Let $p(i|j)$ be the probability that the agency inspects firm i if ambient inspections show that j firms comply and the others do not comply.

Let $\mu(i|j)$ be the agency's belief that firm i does not comply given that this information set has been reached. If the firms play the same strategy, then consistency requires $\mu(i|j) = \frac{n-j}{n}$.

It is straightforward to see that expected costs for the agency when this information set has been reached are:

$$a + (n-j)D_{nc} + jD_c + \sum_{i=1}^n p(i|j) \left\{ b - \frac{n-j}{n} \Delta \right\} \quad (1)$$

Indeed, if the agency does not inspect any firm when this information set has been reached, its expected costs are $a + (n-j)D_{nc} + jD_c$. If it inspects firm i , its costs increase by $b - \frac{n-j}{n} \Delta$.

Excluding the limiting case $b = \frac{n-j}{n} \Delta$,² we can immediately conclude that if ambient inspections show that j firms comply

- the agency will inspect all firms with certainty if $b < \frac{n-j}{n} \Delta$; the agency's expected costs if this information set has been reached are then $a + nb - (n-j) \Delta + (n-j)D_{nc} + jD_c$.
- it will never inspect any firm if $b > \frac{n-j}{n} \Delta$; the agency's expected costs if this information set has been reached are then $a + (n-j)D_{nc} + jD_c$.

Now note that $\forall i < j, b < \frac{n-j}{n} \Delta$ implies $b < \frac{n-i}{n} \Delta$. In words, if it is sequentially rational to inspect all firms if j firms comply, then it is certainly sequentially rational to inspect all firms if less than j firms comply.

Moreover, because $\Delta > b$, there exists a natural number k such that $\frac{n-k-1}{n} \Delta < b < \frac{n-k}{n} \Delta$. This number exists and is unique, because $\frac{n-k-1}{n} \Delta < b < \frac{n-k}{n} \Delta \Leftrightarrow \frac{n(\Delta-b)}{\Delta} > k > \frac{(n-1)\Delta-nb}{\Delta}$ and $\frac{n(\Delta-b)}{\Delta} - \frac{(n-1)\Delta-nb}{\Delta} = 1$.

This implies immediately:

Lemma 1 *For any number of polluting firms n , there exists one and only one critical number of complying firms $k(n)$ such that $\frac{n-k-1}{n} \Delta < b < \frac{n-k}{n} \Delta$, and thus that*

- the agency will inspect all firms with certainty if ambient inspections show that k firms or less comply;
- the agency will not inspect any firm if ambient inspections show that $k+1$ firms or more comply

In other words, sequential rationality requires that the agency uses a “threshold strategy”. As long as ambient pollution does not exceed an endogenous threshold, the costs of inspecting the firms are higher than the expected environmental benefits of putting them in compliance. Ambient inspections thus allow to avoid inspection costs that are suboptimal *ex post*. Note that as long as the firms play the same strategy, the threshold is independent from the firms' behavior: it only depends on n , b and Δ .

If all the firms comply with probability p_α , then the probability that a given number j out of the n firms comply follows the binomial distribution $\binom{n}{j} (1 - p_\alpha)^{n-j} (p_\alpha)^j$ (where $\binom{n}{j} = \frac{n!}{j!(n-j)!}$).

To simplify notation, let $p_{p_\alpha, j}^n = \binom{n}{j} (1 - p_\alpha)^{n-j} (p_\alpha)^j$.

If the agency and the firms play their equilibrium strategy, then the probability that the agency will inspect the firms is equal to $(1 - p_\alpha)^n + \sum_{j=1}^k p_{p_\alpha, j}^n$. With a slight abuse of notation, we shall from now on write:

- $\sum_{j=0}^k p_{p_\alpha, j}^n$ instead of $(1 - p_\alpha)^n + \sum_{j=1}^k p_{p_\alpha, j}^n$, which is correct as long as $p_\alpha > 0$. If $p_\alpha = 0$, then $(1 - p_\alpha)^n + \sum_{j=1}^k p_{p_\alpha, j}^n = 1$.
- $\sum_{j=k+1}^n p_{p_\alpha, j}^n j$ instead of $\{\sum_{j=k+1}^{n-1} p_{p_\alpha, j}^n j\} + (p_\alpha)^n n$, which is correct as long as $p_\alpha < 1$. If $p_\alpha = 1$, then $\{\sum_{j=k+1}^{n-1} p_{p_\alpha, j}^n j\} + (p_\alpha)^n n = n$.

Thus, if the agency conducts ambient inspections followed by sequentially rational firm inspections, its expected costs ($C_a^{k,n}$) in equilibrium are :

$$C_a^{k,n} = a + \left\{ \sum_{j=0}^k p_{p_\alpha, j}^n [nb + (n-j)D_{nc} + jD_c - (n-j)\Delta] \right\} + \left\{ \sum_{j=k+1}^n p_{p_\alpha, j}^n [(n-j)D_{nc} + jD_c] \right\} \quad (2)$$

Indeed, the probability that the agency will reach an information set where j firms comply is $p_{p_\alpha, j}^n$. If $j \leq k$, all firms are inspected and the agency's expected costs in the information set are $a + nb + (n-j)D_{nc} + jD_c - (n-j)\Delta$. If $j > k$, no firm is inspected and the agency's expected costs in the information set are $a + (n-j)D_{nc} + jD_c$.

$C_a^{k,n}$ can be simplified to:

$$a + \sum_{j=0}^k p_{p_\alpha, j}^n n(b - \Delta) + nD_{nc} + [D_c - D_{nc} + \Delta] \left\{ \sum_{j=0}^k p_{p_\alpha, j}^n j \right\} + [D_c - D_{nc}] \left\{ \sum_{j=k+1}^n p_{p_\alpha, j}^n j \right\} \quad (3)$$

2.2 Without ambient inspections

Now suppose that the agency does not conduct ambient inspections:

- If the agency does not inspect the firms, its expected costs are:

$$np_\alpha D_c + n(1 - p_\alpha)D_{nc} \quad (4)$$

- If the agency inspects all firms individually, its expected costs are:

$$np_\alpha D_c + n(1 - p_\alpha)D_{nc} + nb - n(1 - p_\alpha)\Delta \quad (5)$$

Thus, if the agency does not conduct ambient inspections, it will inspect all firms iff $(1 - p_\alpha)\Delta > b$. Note that this condition can be rewritten as $\frac{\Delta - b}{\Delta} > p_\alpha$.

2.3 The best response

Let $\nabla_1^{na,a}(p_\alpha)$ be the difference between the agency's expected costs without and with ambient inspections if $\frac{\Delta - b}{\Delta} \geq p_\alpha$. Equations 3 and 5 imply that:

$$\begin{aligned} \nabla_1^{na,a}(p_\alpha) = & np_\alpha D_c + n(1 - p_\alpha)D_{nc} + nb - n(1 - p_\alpha)\Delta \\ & - a - \sum_{j=0}^k p_{p_\alpha,j}^n n(b - \Delta) - nD_{nc} - [D_c - D_{nc} + \Delta] \left\{ \sum_{j=0}^k p_{p_\alpha,j}^n j \right\} \\ & - [D_c - D_{nc}] \left\{ \sum_{j=k+1}^n p_{p_\alpha,j}^n j \right\} \end{aligned}$$

Clearly, if $\frac{\Delta - b}{\Delta} \geq p_\alpha$, then the agency will conduct ambient inspections if and only if $\nabla_1^{na,a}(p_\alpha) > 0$.

Let $\nabla_2^{na,a}(p_\alpha)$ be the difference between the agency's expected without and with ambient inspections if $p_\alpha \geq \frac{\Delta - b}{\Delta}$. Equations 3 and 4 imply that:

$$\begin{aligned} \nabla_2^{na,a}(p_\alpha) = & np_\alpha D_c + n(1 - p_\alpha)D_{nc} \\ & - a - \sum_{j=0}^k p_{p_\alpha,j}^n n(b - \Delta) - nD_{nc} - [D_c - D_{nc} + \Delta] \left\{ \sum_{j=0}^k p_{p_\alpha,j}^n j \right\} \\ & - [D_c - D_{nc}] \left\{ \sum_{j=k+1}^n p_{p_\alpha,j}^n j \right\} \end{aligned}$$

Clearly, if $p_\alpha \geq \frac{\Delta - b}{\Delta}$, then the agency will conduct ambient inspections if and only if $\nabla_2^{na,a}(p_\alpha) > 0$.

Also, $\nabla_1^{na,a}\left(\frac{\Delta - b}{\Delta}\right) = \nabla_2^{na,a}\left(\frac{\Delta - b}{\Delta}\right)$.

In Appendix A, we shall proof the following Lemma's:

- **Lemma 2** $\nabla_1^{na,a}(0) < 0$.

In words, if the firms never comply, the agency's best response is not to conduct ambient inspections but to inspect all firms individually.

- **Lemma 3** $\nabla_1^{na,a}(p_\alpha)$ is increasing in p_α .

In words, if $\frac{\Delta-b}{\Delta} \geq p_\alpha$, the higher p_α , the more likely that the agency will prefer to conduct ambient inspections.

- **Lemma 4** $\nabla_2^{na,a}(1) < 0$.

In words, if the firms always comply, the agency's best response is not to conduct any inspections at all.

- **Lemma 5** $\nabla_2^{na,a}(p_\alpha)$ is decreasing in p_α .

In words, if $p_\alpha \geq \frac{\Delta-b}{\Delta}$, the higher p_α , the more likely that the agency will prefer not to conduct ambient inspections.

From these Lemma's, we can immediately see the agency's best response to any given p_α .

Suppose now first that $\nabla_1^{na,a}(\frac{\Delta-b}{\Delta}) < 0$. Lemma's 2, 3, 4 and 5 then imply that $\nabla_1^{na,a}(p_\alpha) < 0$ for all p_α and we obtain immediately:

Lemma 6 *If $\nabla_1^{na,a}(\frac{\Delta-b}{\Delta}) < 0$, the agency will never conduct ambient inspections; it will inspect all firms if $\frac{\Delta-b}{\Delta} > p_\alpha$; it will not inspect any firm if $\frac{\Delta-b}{\Delta} < p_\alpha$ and it will be indifferent between inspecting the firms and not inspecting the firms if $\frac{\Delta-b}{\Delta} = p_\alpha$.*

Suppose next that $\nabla_1^{na,a}(\frac{\Delta-b}{\Delta}) > 0$ (we shall not consider limiting cases like $\nabla_1^{na,a}(\frac{\Delta-b}{\Delta}) = 0$).

- Lemma's 2 and 3 imply then that there exists one and only one p_α^{1*} such that $\frac{\Delta-b}{\Delta} > p_\alpha^{1*}$ and such that $\nabla_1^{na,a}(p_\alpha^{1*}) = 0$.

The agency's best response to $\frac{\Delta-b}{\Delta} > p_\alpha$ is thus :

- not to conduct ambient inspections but to inspect all firms individually if $p_\alpha^{1*} > p_\alpha$
- to conduct ambient inspections (followed by sequentially rational firm inspections) if $p_\alpha > p_\alpha^{1*}$

- Lemma's 4 and 5 imply that there exists at one and only one p_α^{2*} such that $p_\alpha^{2*} > \frac{\Delta-b}{\Delta}$ and such that $\nabla_2^{na,a}(p_\alpha^{2*}) = 0$.

The agency's best response to $p_\alpha > \frac{\Delta-b}{\Delta}$ is thus:

- not to conduct any inspections at all (neither ambient inspections nor firm inspections) if $p_\alpha > p_\alpha^{2*}$
- to conduct ambient inspections (followed by sequentially rational firm inspections) if $p_\alpha^{2*} > p_\alpha$

We can conclude:

Lemma 7 *If $\nabla_1^{na,a}(\frac{\Delta-b}{\Delta}) > 0$, the agency's best response is:*

- *If $p_\alpha^{1*} > p_\alpha$, then the agency does not conduct ambient inspections but inspects all firms individually.*
- *If $p_\alpha^{1*} = p_\alpha$, then the agency is indifferent between conducting and not conducting ambient inspections; if the agency conducts ambient inspections, they are followed by sequentially rational firm inspections; if the agency does not conduct ambient inspections, it inspects all firms individually.*
- *If $p_\alpha^{2*} > p_\alpha > p_\alpha^{1*}$, then the agency conducts ambient inspections (followed by sequentially rational firm inspections).*
- *If $p_\alpha^{2*} = p_\alpha$, then the agency is indifferent between conducting and not conducting ambient inspections; if the agency conducts ambient inspections, they are followed by sequentially rational firm inspections; if the agency does not conduct ambient inspections, it does not inspect the firms.*
- *If $p_\alpha > p_\alpha^{2*}$, the agency does not conduct any inspections at all (neither ambient inspections nor firm inspections).*

The intuition behind this result is straightforward. The advantage of ambient inspections is that they allow better informed firm inspections: the “threshold strategy” implies that firms will only be inspected if, given the information embodied in ambient pollution levels, it is worth the while. Indeed, with ambient inspections, the probability that the probability that the agency will inspect the firms is decreasing in the probability of compliance:

Lemma 8

$$\frac{d \sum_{j=0}^k p_{p_\alpha, j}^n}{dp_\alpha} = -n p_{p_\alpha, k}^{n-1} < 0$$

Proof

Note first that for all j such that $j \leq n - 1$:

$$\begin{aligned} \frac{dp_{p_\alpha, j}^n}{dp_\alpha} &= \\ -\binom{n}{j} (n-j)(1-p_\alpha)^{n-j-1}(p_\alpha)^j + \binom{n}{j} (1-p_\alpha)^{n-j} j(p_\alpha)^{j-1} &= \\ -n \binom{n-j-1}{j} (1-p_\alpha)^{n-j-1}(p_\alpha)^j + n \binom{n-1}{j-1} (1-p_\alpha)^{n-j} (p_\alpha)^{j-1} &= \\ n\{p_{p_\alpha, j-1}^{n-1} - p_{p_\alpha, j}^{n-1}\} & \quad (6) \end{aligned}$$

Equation 6 implies immediately:

$$\frac{d \sum_{j=0}^k p_{p_\alpha, j}^n}{dp_\alpha} = -n(1-p_\alpha)^{n-1} + n \sum_{j=1}^k \{p_{p_\alpha, j-1}^{n-1} - p_{p_\alpha, j}^{n-1}\}$$

Now note that $-n(1-p_\alpha)^{n-1} + \binom{n}{1}(1-p_\alpha)^{n-1} = 0$. The rest of the proof is obvious. \square QED \square

It is straightforward to verify that were ambient inspections costless ($a = 0$), the agency would always conduct ambient inspections. However, with very low probabilities of compliance ($p_\alpha^{1*} > p_\alpha$), the *ex ante* probability that the agency will decide to inspect all firms after having observed ambient pollution becomes so high that gathering this information is not worth the while if it costly. On the other hand, with very high probabilities of compliance ($p_\alpha > p_\alpha^{2*}$), the *ex ante* probability that the agency will decide *not* to inspect any firm after having observed ambient pollution, becomes so high that gathering this information is not worth the while either. Thus, *ambient inspections are only a best response to intermediate probabilities of compliance.*

3 The firms' best response

If a firm complies, its expected costs are always α . If a noncompliant firm is not inspected, its expected costs are zero. If a noncompliant firm is inspected, its expected costs are $\Psi + \gamma\alpha$.

If $(1-\gamma)\alpha > \Psi$, then the firm will never comply, even if it is inspected with certainty. Therefore, we shall from now on assume that $\Psi > (1-\gamma)\alpha$.

Before proceeding further with the analysis, we can immediately eliminate some possible equilibria.

First, if the agency does not conduct any inspections at all, then the firms' optimal response obviously is not to comply. However, if the firms never comply, the agency's best response is to inspect all firms individually (Lemma 2), so this can never be part of a NE.

Suppose next that the agency inspects all firms individually. The firms will always comply, but then the agency's best response is not to conduct any inspections at all (Lemma 4), so this can never be part of a NE either.

This argument shows:

Lemma 9 *There is no NE where the firms play pure strategies, where the agency inspects all firms with certainty or where the agency does never inspect a firm.*

In what follows, we shall now determine all the possible equilibria, first if $\nabla_1^{na,a}(\frac{\Delta-b}{\Delta}) < 0$ (Section 3.1), and next if $\nabla_1^{na,a}(\frac{\Delta-b}{\Delta}) > 0$ (Section 3.2).

3.1 $\nabla_1^{na,a}(\frac{\Delta-b}{\Delta}) < 0$

From Lemma 6, the agency never conducts ambient inspections. This implies that the optimal strategy for firm i is always independent from the choices made by the other firms.

Let p_i be the probability that firm i is inspected. Firm i 's expected costs when it does not comply are then: $p_i(\Psi + \gamma\alpha)$.

Let p_i^α be the probability that firm i complies in a mixed strategy. Firm i 's expected cost is then:

$$p_i^\alpha \alpha + (1 - p_i^\alpha)[p_i(\Psi + \gamma\alpha) + (1 - p_i) \cdot 0] = p_i(\Psi + \gamma\alpha) + p_i^\alpha(\alpha - p_i(\Psi + \gamma\alpha)) \quad (7)$$

Expected costs are linear in p_i^α , which implies that they are increasing in p_i^α iff $(\Psi + \gamma\alpha)p_i < \alpha$. If $\Psi > (1 - \gamma)\alpha$, then $1 > \frac{\alpha}{\Psi + \gamma\alpha} > 0$. Firm i then complies if $p_i > \frac{\alpha}{\Psi + \gamma\alpha}$, does not comply if $p_i < \frac{\alpha}{\Psi + \gamma\alpha}$ and is indifferent between complying and not complying if $p_i = \frac{\alpha}{\Psi + \gamma\alpha}$. If we combine this with Lemma 6, we obtain the firms' and the agency's reaction function (see figure 1), and we can conclude:

Proposition 2 *If $\nabla_1^{na,a}(\frac{\Delta-b}{\Delta}) < 0$, the following strategy pair is the unique NE: the firms comply with probability $p_\alpha = \frac{\Delta-b}{\Delta}$, the agency does not conduct ambient inspections but inspects the firms with probability $p_i = \frac{\alpha}{\Psi + \gamma\alpha}$.*

Comments

1. This is exactly the equilibrium in the game without ambient inspections and with $\gamma = 1$ analyzed in Franckx (2002a).
2. If all players play their equilibrium strategy, the expected cost for the inspection agency is:

$$n\left\{\frac{b}{\Delta}D_{nc} + \left(1 - \frac{b}{\Delta}\right)D_c\right\} \quad (8)$$

In a mixed-strategy equilibrium, the firms are indifferent between complying and not complying. This means that their expected costs in equilibrium are simply the compliance cost α .

3. If Δ is independent from the fine, then the probability of compliance does *not* depend on the magnitude of the fine. Indeed, in a Nash equilibrium, firms choose the probability of compliance to make the agency indifferent between inspecting and not inspecting them. If the fine has no intrinsic utility for the agency, then it should not play a role in the equilibrium strategy for the firms.

The only role the fine plays in this game is that when the size of the fine increases, the equilibrium probability of inspection can go down. However,

total expected costs for the agency are independent of the fine, because the firms' strategies make the agency indifferent with respect to the probability of inspection (and all terms that include the probability of inspection disappear from the agency's expected costs).

4. Suppose that the agency can commit to an inspection probability that is infinitesimally larger than $\frac{\alpha}{\Psi + \gamma\alpha}$. The agency then obtains perfect compliance and its expected costs are approximately:

$$n\left[\frac{\alpha}{\Psi + \gamma\alpha}b + D_c\right]$$

Compare this with Equation 8: $\frac{D_{nc} - D_c}{\Delta} > 1 > \frac{\alpha}{\Psi + \gamma\alpha}$ and the agency's expected costs are higher under the no-commitment hypothesis.

The reason is that if the agency is not committed to its inspection policy, its best response if all firms comply is not to inspect any firm. If inspecting firms were costless ($b = 0$), this distinction between commitment and no-commitment would however disappear.

3.2 $\nabla_1^{na,a}\left(\frac{\Delta - b}{\Delta}\right) > 0$

Lemma's 7 and 9 imply that if $\nabla_1^{na,a}\left(\frac{\Delta - b}{\Delta}\right) > 0$, we have to consider the firm's best response to the following strategies:

- the agency mixes between conducting ambient inspections and not conducting ambient inspections, but always inspects the firms if it does not conduct ambient inspections (strategy I)
- the agency mixes between conducting ambient inspections and not conducting ambient inspections, and never inspects the firms if it does not conduct ambient inspections (strategy II)
- the agency always conducts ambient inspections, followed by sequentially rational firm inspections (strategy III)

After having verified for each strategy whether an equilibrium exists where this strategy is played, we shall show existence and uniqueness in Section 3.2.4. Finally, we determine the optimal level of the fine from the agency's point of view in Section 3.2.5.

3.2.1 strategy I

First suppose that the agency mixes between conducting ambient inspections and not conducting ambient inspections, but always inspects the firms if it does not conduct ambient inspections. Firm i 's expected costs become (where p^a is the probability that the agency conducts ambient inspections):

$$(1 - p^a)[p_i^\alpha \alpha + (1 - p_i^\alpha)(\Psi + \gamma\alpha)] \\ + p^a[p_i^\alpha \alpha + (1 - p_i^\alpha) \sum_{j=0}^k p_{p_\alpha, j}^{n-1} (\Psi + \gamma\alpha)]$$

The first term are the firm's expected costs if the agency does not conduct ambient inspections, the second term are the firm's expected costs if the agency conducts ambient inspections.

Indeed, with ambient inspections, the conditions for sequential rationality imply that the probability that firm i will be inspected if it does not comply is the probability that at most k of the $n-1$ other firms comply, this is $\sum_{j=0}^k p_{p_\alpha, j}^{n-1}$.

Rearranging terms, we see that the firm's expected costs are also equal to:

$$(1 - p^a)[\Psi + \gamma\alpha + p_i^\alpha \{(1 - \gamma)\alpha - \Psi\}] \\ + p^a[(\Psi + \gamma\alpha) \sum_{j=0}^k p_{p_\alpha, j}^{n-1} + p_i^\alpha \{\alpha - (\Psi + \gamma\alpha) \sum_{j=0}^k p_{p_\alpha, j}^{n-1}\}] = \\ (1 - p^a)[\Psi + \gamma\alpha] + p^a[\Psi + \gamma\alpha] \sum_{j=0}^k p_{p_\alpha, j}^{n-1} \\ + p_i^\alpha [(1 - p^a)\{(1 - \gamma)\alpha - \Psi\} + p^a\{\alpha - (\Psi + \gamma\alpha) \sum_{j=0}^k p_{p_\alpha, j}^{n-1}\}]$$

We know from Lemma 7 that the agency will only play strategy I if $p_\alpha = p_\alpha^{1*}$. Firm i will play a mixed strategy if and only if it is indifferent with respect to its choice of p_i^α , thus iff:

$$(1 - p^a)\{(1 - \gamma)\alpha - \Psi\} + p^a\{\alpha - (\Psi + \gamma\alpha) \sum_{j=0}^k p_{p_\alpha^{1*}, j}^{n-1}\} = 0$$

Thus, if and only if the agency plays a mixed strategy such that:

$$p^a = \frac{\Psi - (1 - \gamma)\alpha}{(\Psi + \gamma\alpha)(1 - \sum_{j=0}^k p_{p_\alpha^{1*}, j}^{n-1})}$$

It is clear that $\frac{\Psi - (1 - \gamma)\alpha}{(\Psi + \gamma\alpha)(1 - \sum_{j=0}^k p_{p_\alpha^{1*}, j}^{n-1})} \geq 0$. However, this is only a probability if $\frac{\Psi - (1 - \gamma)\alpha}{(\Psi + \gamma\alpha)(1 - \sum_{j=0}^k p_{p_\alpha^{1*}, j}^{n-1})} \leq 1$, which is equivalent with $\sum_{j=0}^k p_{p_\alpha^{1*}, j}^{n-1} \leq \frac{\alpha}{\Psi + \gamma\alpha}$.

Combining this argument with Lemma 7 allows us to conclude:

Lemma 10 If $\nabla_1^{na,a}(\frac{\Delta-b}{\Delta}) > 0$ and if $\sum_{j=0}^k p_{p_\alpha^{1*},j}^{n-1} \leq \frac{\alpha}{\Psi+\gamma\alpha}$, then the following strategy pair is a PBE:

- the firms comply with probability p_α^{1*}
- the agency conducts ambient inspections (followed by sequentially rational firm inspections) with probability $\frac{\Psi-(1-\gamma)\alpha}{(\Psi+\gamma\alpha)(1-\sum_{j=0}^k p_{p_\alpha^{1*},j}^{n-1})}$ and inspects all firms if it does not conduct ambient inspections.

If $\sum_{j=0}^k p_{p_\alpha^{1*},j}^{n-1} > \frac{\alpha}{\Psi+\gamma\alpha}$, then $(1-p^a)\{(1-\gamma)\alpha-\Psi\}+p^a\{\alpha-(\Psi+\gamma\alpha)\sum_{j=0}^k p_{p_\alpha^{1*},j}^{n-1}\} < 0$. Whatever the probability that the agency conducts ambient inspections and whatever the other firms' probability of compliance, firm i will then always comply, but this can never be part of a NE (see Lemma 5).

Thus:

Lemma 11 If $\sum_{j=0}^k p_{p_\alpha^{1*},j}^{n-1} > \frac{\alpha}{\Psi+\gamma\alpha}$, there is no NE where the firms comply with probability p_α^{1*} .

3.2.2 strategy II

Next, suppose that the agency mixes between conducting ambient inspections and not conducting ambient inspections, but never inspects the firms if it does not conduct ambient inspections. Firm i 's expected costs become:

$$(1-p^a)p_i^\alpha\alpha + p^a[(\Psi+\gamma\alpha)\sum_{j=0}^k p_{p_\alpha,j}^{n-1} + p_i^\alpha\{\alpha-(\Psi+\gamma\alpha)\sum_{j=0}^k p_{p_\alpha,j}^{n-1}\}]$$

The first term are the firm's expected costs if the agency does not conduct ambient inspections, the second term are the firm's expected costs if the agency conducts ambient inspections.

Rearranging terms, we see that this expression is equal to:

$$p^a(\Psi+\gamma\alpha)\sum_{j=0}^k p_{p_\alpha,j}^{n-1} + p_i^\alpha[(1-p^a)\alpha + p^a\{\alpha-(\Psi+\gamma\alpha)\sum_{j=0}^k p_{p_\alpha,j}^{n-1}\}]$$

We know that from Lemma 7 the agency will only play strategy II if $p_\alpha = p_\alpha^{2*}$.

Firm i will only play a mixed strategy if it is indifferent with respect to the choice of p_i^α , thus if:

$$(1-p^a)\alpha + p^a\{\alpha-(\Psi+\gamma\alpha)\sum_{j=0}^k p_{p_\alpha^{2*},j}^{n-1}\} = 0$$

Thus, if and only if the agency plays a mixed strategy such that:

$$p^a = \frac{\alpha}{(\Psi + \gamma\alpha) \sum_{j=0}^k p_{p_\alpha^{2^*}, j}^{n-1}}$$

It is clear that $\frac{\alpha}{(\Psi + \gamma\alpha) \sum_{j=0}^k p_{p_\alpha^{2^*}, j}^{n-1}} > 0$. However, this is only a probability if $\frac{\alpha}{(\Psi + \gamma\alpha) \sum_{j=0}^k p_{p_\alpha^{2^*}, j}^{n-1}} \leq 1$, thus if $\sum_{j=0}^k p_{p_\alpha^{2^*}, j}^{n-1} \geq \frac{\alpha}{\Psi + \gamma\alpha}$.

Combining this argument with Lemma 7 allows us to conclude:

Lemma 12 *If $\nabla_1^{na, a}(\frac{\Delta - b}{\Delta}) > 0$, and if $\sum_{j=0}^k p_{p_\alpha^{2^*}, j}^{n-1} \geq \frac{\alpha}{\Psi + \gamma\alpha}$, then the following strategy pair is a PBE:*

- the firms comply with probability $p_\alpha^{2^*}$
- the agency conducts ambient inspections (followed by sequentially rational firm inspections) with probability $\frac{\alpha}{(\Psi + \gamma\alpha) \sum_{j=0}^k p_{p_\alpha^{2^*}, j}^{n-1}}$ but never inspects the firms if it does not conduct ambient inspections.

If $\sum_{j=0}^k p_{p_\alpha^{2^*}, j}^{n-1} < \frac{\alpha}{\Psi + \gamma\alpha}$, then $(1 - p^a)\alpha + p^a\{\alpha - (\Psi + \gamma\alpha) \sum_{j=0}^k p_{p_\alpha^{2^*}, j}^{n-1}\} > 0$. Whatever the probability that the agency conducts ambient inspections and whatever the other firms' probability of compliance, the firm's optimal reaction consists in never complying, but this can never be part of a NE (see Lemma 5).

Lemma 13 *If $\sum_{j=0}^k p_{p_\alpha^{2^*}, j}^{n-1} < \frac{\alpha}{\Psi + \gamma\alpha}$, there is no NE where the firms comply with probability $p_\alpha^{2^*}$.*

3.2.3 strategy III

Finally, suppose that the agency always conducts ambient inspections. From the discussion above, we know that firm i 's expected cost is then:

$$(\Psi + \gamma\alpha) \sum_{j=0}^k p_{p_\alpha, j}^{n-1} + p_i^\alpha \{\alpha - (\Psi + \gamma\alpha) \sum_{j=0}^k p_{p_\alpha, j}^{n-1}\}$$

Any given firm i will play a mixed strategy iff it is indifferent with respect to its choice of p_i^α , thus iff $\alpha - (\Psi + \gamma\alpha) \sum_{j=0}^k p_{p_\alpha, j}^{n-1} = 0$ when the other firms play their equilibrium strategy. We need thus to show that there exists a unique value of p_α such that this equality is true. One possible way to do this is to show that $\alpha - (\Psi + \gamma\alpha) \sum_{j=0}^k p_{p_\alpha, j}^{n-1}$ is a strictly monotonous function of p_α and that its sign changes in the domain.

Lemma 8 implies directly that $\alpha - (\Psi + \gamma\alpha) \sum_{j=0}^k p_{p_\alpha, j}^{n-1}$ is strictly increasing in p_α . If $p_\alpha = 0$, then $\alpha - (\Psi + \gamma\alpha) \sum_{j=0}^k p_{p_\alpha, j}^{n-1} = (1 - \gamma)\alpha - \Psi < 0$. If $p_\alpha = 1$,

then $\alpha - (\Psi + \gamma\alpha) \sum_{j=0}^k p_{p_{\alpha,j}}^{n-1} = \alpha > 0$. There must thus indeed be a unique value $p_{\alpha} \in]0, 1[$ such that $\alpha - (\Psi + \gamma\alpha) \sum_{j=0}^k p_{p_{\alpha,j}}^{n-1} = 0$.

Combining this argument with Lemma 7 allows us to conclude:

Lemma 14 *If $\nabla_1^{na,a}(\frac{\Delta-b}{\Delta}) > 0$, and if there exists a $p_{\alpha}^* \in]p_{\alpha}^{1*}, p_{\alpha}^{2*}[$ such that $\alpha - (\Psi + \gamma\alpha) \sum_{j=0}^k p_{c,j,p_{\alpha}^*}^{n-1} = 0$, then the following strategy pair is a PBE:*

- *the firms comply with probability p_{α}^**
- *the agency always conducts ambient inspections followed by sequentially rational firms inspections*

3.2.4 Existence and uniqueness

It remains now to be shown that we indeed have a unique PBE for all possible parameter values.

Note first that Lemma 8 implies $\frac{d \sum_{j=0}^k p_{p_{\alpha,j}}^{n-1}}{dp_{\alpha}} < 0$ and thus $\sum_{j=0}^k p_{p_{\alpha}^{2*},j}^{n-1} < \sum_{j=0}^k p_{p_{\alpha}^{1*},j}^{n-1}$. Therefore, it is impossible to have $\sum_{j=0}^k p_{p_{\alpha}^{2*},j}^{n-1} \geq \frac{\alpha}{\Psi + \gamma\alpha} \geq \sum_{j=0}^k p_{p_{\alpha}^{1*},j}^{n-1}$. In words, it is impossible to have the PBE from Lemma 10 and 12 simultaneously.

Suppose now that we have $\sum_{j=0}^k p_{p_{\alpha}^{1*},j}^{n-1} > \frac{\alpha}{\Psi + \gamma\alpha} > \sum_{j=0}^k p_{p_{\alpha}^{2*},j}^{n-1}$, and thus that the PBE from Lemma 10 and 12 do not exist. Lemma 8 then implies that p_{α}^* does indeed exist and we conclude:

Proposition 3 *If $\nabla_1^{na,a}(\frac{\Delta-b}{\Delta}) > 0$, the following strategy pairs are the unique PBE:*

- *If $\frac{\alpha}{\Psi + \gamma\alpha} \geq \sum_{j=0}^k p_{p_{\alpha}^{1*},j}^{n-1}$: see Lemma 10*
- *If $\sum_{j=0}^k p_{p_{\alpha}^{1*},j}^{n-1} > \frac{\alpha}{\Psi + \gamma\alpha} > \sum_{j=0}^k p_{p_{\alpha}^{2*},j}^{n-1}$: see Lemma 14*
- *If $\sum_{j=0}^k p_{p_{\alpha}^{2*},j}^{n-1} \geq \frac{\alpha}{\Psi + \gamma\alpha}$: see Lemma 12*

3.2.5 The optimal fine

The intuition behind Proposition 3 is not straightforward to see. This changes however if we ask the following question: suppose that the agency could determine herself the fine that we have assumed to be exogenous in this model, what would be her choice?

To answer this question, we first introduce $\Gamma(p_{\alpha})$ as short hand notation for

$$\alpha \frac{1 - \gamma \sum_{j=0}^k p_{p_{\alpha,j}}^{n-1}}{\sum_{j=0}^k p_{p_{\alpha,j}}^{n-1}}.$$

The conditions in Proposition 3 can then be rewritten as follows:

- $\frac{\alpha}{\Psi + \gamma\alpha} \geq \sum_{j=0}^k p_{p_{\alpha}^{1*},j}^{n-1}$ is equivalent with $\Gamma(p_{\alpha}^{1*}) \geq \Psi$.

- $\sum_{j=0}^k p_{p_\alpha^{1*},j}^{n-1} > \frac{\alpha}{\Psi+\gamma\alpha} > \sum_{j=0}^k p_{p_\alpha^{2*},j}^{n-1}$ is equivalent with $\Gamma(p_\alpha^{2*}) > \Psi > \Gamma(p_\alpha^{1*})$.
- $\sum_{j=0}^k p_{p_\alpha^{2*},j}^{n-1} \geq \frac{\alpha}{\Psi+\gamma\alpha}$ is equivalent with $\Psi \geq \Gamma(p_\alpha^{2*})$

Next, note the following Lemma (for the proof, see Appendix B)

Lemma 15 *If $\Gamma(p_\alpha^{2*}) \geq \Psi \geq \Gamma(p_\alpha^{1*})$, then the agency's expected costs are decreasing in the fine.*

We shall now look at the optimal fines for all the possible relative values.

- If $\Gamma(p_\alpha^{1*}) \geq \Psi$, the agency is indifferent between conducting ambient inspections and inspecting all firms. Its expected costs are thus $C_a^{k,n}(p_\alpha^{1*})$. These costs are independent from the level of the fine (indeed, remember that $\nabla_1^{n,a}(p_\alpha^{1*}) = 0$).
- If $\Gamma(p_\alpha^{2*}) > \Psi > \Gamma(p_\alpha^{1*})$, the agency always conducts ambient inspections, the firms comply with probability p_α^* and the agency's expected costs are $C_a^{k,n}(p_\alpha^*)$. Moreover, Lemma 15 implies that $C_a^{k,n}(p_\alpha^*) < C_a^{k,n}(p_\alpha^{1*})$, and thus that it can never be optimal to set a fine such that the firms comply with probability p_α^{1*} .
- Finally, if $\Psi \geq \Gamma(p_\alpha^{2*})$, the agency's expected costs are $C_a^{k,n}(p_\alpha^{2*})$. Lemma 15 implies $C_a^{k,n}(p_\alpha^{2*}) < C_a^{k,n}(p_\alpha^*)$, and thus it can never be optimal to set a fine such that the firms comply with probability p_α^* .

We can conclude immediately:

Proposition 4 *Suppose that $\nabla_1^{n,a}(\frac{\Delta-b}{\Delta}) > 0$. The optimal fine is any Ψ such that $\Psi \geq \Gamma(p_\alpha^{2*})$. The agency then conducts ambient inspections (followed by sequentially rational firm inspections) with probability $\frac{\alpha}{(\Psi+\gamma\alpha)\sum_{j=0}^k p_{p_\alpha^{2*},j}^{n-1}}$ but never inspects the firms if it does not conduct ambient inspections; the firms comply with probability p_α^{2*} .*

Lemma 15 (the agency's expected costs with ambient inspections are decreasing in the fine) and Equation 8 (the agency's expected costs without ambient inspections are independent from the fine) tell us immediately why the agency wants the fine to be as high as possible.

Therefore, it is worthwhile to understand why Lemma 15 holds.

Before inspection, the agency's expected costs with ambient inspections are:

$$a + (n - \sum_{j=0}^n p_{p_\alpha,j}^n) D_{nc} + (\sum_{j=0}^n p_{p_\alpha,j}^n j) D_c$$

An increase in the probability of compliance means that more firms comply spontaneously. Equations 10 and 11 (see Appendix A) imply that

$$\frac{dnD_{nc} + [D_c - D_{nc}]\{\sum_{j=0}^n p_{p_\alpha, j}^n j\}}{dp_\alpha} = n[D_c - D_{nc}] < 0$$

Thus, the direct effect is that expected costs of noncompliance decrease.

Expected firm inspection costs are: $\sum_{j=0}^k p_{p_\alpha, j}^n nb$. From Lemma 8, we know that $\frac{d \sum_{j=0}^k p_{p_\alpha, j}^n}{dp_\alpha} < 0$. This means that expected firm inspections costs decrease when the probability of compliance increases. Indeed, if the probability of compliance increases, then the probability that the inspection threshold will be reached (and thus the probability that *all* firms will be inspected) decreases.

On the other hand, if the probability that the inspection threshold will be reached decreases, then the probability that the noncompliant firms will be put in compliance also decreases. Equations 9 and 10 (see Appendix A) imply that

$$\frac{d \sum_{j=0}^k p_{p_\alpha, j}^n (j - n) \Delta}{dp_\alpha} = \left\{ \left(\sum_{j=0}^{k-1} p_{p_\alpha, j}^{n-1} \right) + p_{p_\alpha, k}^{n-1} (n - k) \right\} \Delta > 0$$

Thus, the indirect effect runs in the direction opposite to the direct effect.

However, remember that we have assumed that, even with zero inspection costs, the agency prefers that the firms comply spontaneously rather than as the result of inspections ($D_{nc} - D_c > \Delta$). Moreover, the inspection threshold is determined in such a way that $nb > (n - k - 1)\Delta$. The Proof in Appendix B shows that this implies that *the positive effects on expected firm inspection costs and on the benefits of spontaneous compliance dominate the negative effect on the benefits of putting noncompliant firms in compliance*.

This explains why the agency wants the probability of compliance to be as high as possible with ambient inspections.

The Proof in Appendix B also shows that the probability of compliance is increasing in the fine. The reason is that if the firms play mixed strategies, their equilibrium strategy must make the other firms indifferent between complying and not complying. As the firms' expected costs depend on the level of the fine, this means that their equilibrium probability of compliance must also depend on the fine.

Now, if the fine increases, the expected costs of a non-compliant firm increase. A firm will thus only remain indifferent between complying and not-complying if the probability that the other firms comply increases, because then the probability of reaching the information sets where they are not inspected increases.

Our explanation for imposing high penalties is thus completely different from the traditional justification given by Becker³.

However, once the fines strictly exceed the threshold $\Gamma(p_\alpha^{2*})$, the probability of compliance with ambient inspections becomes so high that the agency prefers not to inspect any firm at all, but this can never be part of a NE. Therefore, the agency mixes between conducting ambient inspections and not conducting ambient inspections.

Of course, in reality, with upper constraints on the fine (such as the assets of the firm), it might be impossible to impose a fine $\Psi \geq \Gamma(p_\alpha^{2*})$. It might then be optimal to have ambient inspections with certainty. With very strict upper constraints on the fine (the maximal possible fine is smaller than $\Gamma(p_\alpha^{1*})$), it might even be optimal to randomize between conducting ambient inspections and inspecting all firms (independently from ambient pollution).

4 Does commitment matter?

Let us now briefly explore what happens if we revert to the institutional assumptions used in Franckx (2002a) and Franckx (2002b).

First, it is absolutely straightforward to verify that the two technical generalizations we have introduced here do not affect the analysis in Franckx (2002b).

The comparison with Franckx (2002a) is slightly more elaborated. Let us therefore assume that the agency can commit to conducting ambient pollution, even if it cannot commit to firm inspection probabilities. The only change compared to the analysis in the rest of the paper is that it is now common knowledge whether or not the agency observes ambient pollution.

Suppose first that the agency credibly commits to inspecting ambient pollution levels.

In that case, the timing of the game is:

- The firms simultaneously choose their abatement technology, knowing that the agency observes ambient pollution.
- The enforcement agency observes ambient levels
- The enforcement agency chooses the firms it will inspect

Because the agency cannot commit to firm inspection probabilities, we still require the agency's policy to be sequential rational. It can easily be verified that the conditions for sequential rationality obtained in Section 2.1 do not change in this new context.

From the analysis in Section 3.2.3, we know that if the agency always conducts ambient inspections, then there exists a unique equilibrium probability of compliance p_α^* . From Lemma 15, we know that the agency's expected costs with ambient inspections are decreasing in the fine.

Suppose next that the agency credibly commits not to inspect ambient pollution levels. The game then reduces to the game analyzed in Section 3.1.

The difference between expected costs for the agency with and without ambient inspections is then (this follows directly from Equation 3 and 8):

$$a + \sum_{j=0}^k p_\alpha^* n(b - \Delta) + nD_{nc} + [D_c - D_{nc} + \Delta] \left\{ \sum_{j=0}^k p_\alpha^* j \right\}$$

$$+[D_c - D_{nc}]\left\{\sum_{j=k+1}^n p_\alpha^* j\right\} - n\left\{\frac{b}{\Delta}D_{nc} + \left(1 - \frac{b}{\Delta}\right)D_c\right\}$$

From Lemma 15, we can immediately conclude:

Proposition 5 *The difference between the agency’s expected costs with ambient inspections and without ambient inspections are a decreasing function of the fine.*

This is due to the fact that the agency’s expected costs without ambient inspections are independent from the fine. Thus, *the higher the fine set by the legislator, the more likely that the agency will commit to ambient inspections if it has this commitment power.* This is exactly the central result obtained in Franckx (2002a).

On the other hand, from the analysis in Section 3.2.5, we see that this result completely disappears if we drop the assumption that the agency can commit to ambient inspections. Commitment power (or the lack of it) has thus a crucial impact on the outcome of the game.

5 Conclusion

This paper extends previous work by Franckx (2002a,2002b) to a new setting.

We have shown that if the agency can commit to ambient inspections, then the central result obtained in Franckx (2002a) does not change when we relax three apparently strong assumptions (2 polluting firms, the agency’s objective function that does not include private compliance costs, the agency’s power to put noncompliant firms in compliance) as long as the agency prefers the firm to comply spontaneously rather than as the results of inspections. In this respect, the results in Franckx (2002a) are rather robust.

However, if the agency cannot commit to ambient inspections, then our main conclusions are the following. Consider the probability of compliance that makes the agency indifferent between inspecting and not inspecting the firms in a game without ambient inspections.

- Suppose that the agency’s expected costs are lower without ambient inspections if the firms comply with this probability. The agency will then never conduct ambient inspections. If the benefits of inspecting noncompliant firms are independent from the fine, then the probability of compliance and the agency’s expected costs are also independent from the fine.
- Suppose next that the agency’s expected costs are lower with ambient inspections if the firms comply with this probability. The agency’s strategy then depends on the fine for noncompliance. If this fine is very high, then the agency mixes between conducting ambient inspections and not conducting any inspections at all. For intermediate values of the fine, the agency conducts ambient inspections. For very low values of the fine, the

agency mixes between conducting ambient inspections and inspecting all firms. If the agency conducts ambient inspections, it inspects all firms if and only if an endogenous threshold of pollution has been exceeded. If the agency prefers the firm to comply spontaneously rather than as the results of inspections, then expected costs for the agency are a decreasing function of the fine.

These results contradict strongly the key conclusions obtained in Franckx (2002a) and Franckx (2002b). We have thus shown that apparently *small changes in the institutional context* dramatically affect the outcome of the inspection game: commitment power (or the lack of it) really has a very strong impact on the value of prior information and on the role played by the fines for noncompliance.

A Proofs of the results used in Section 2.3

Proof of Lemma 2

If $p_\alpha = 0$, then $\sum_{j=0}^k p_{p_\alpha, j}^n = 1$ and $\sum_{j=0}^k p_{p_\alpha, j}^n j = \sum_{j=k+1}^n p_{p_\alpha, j}^n j = 0$. This implies immediately:

$$\begin{aligned} \nabla_1^{na, a}(p_\alpha = 0) &= nb - n \Delta - a - n[b - \Delta] \\ &< 0 \end{aligned}$$

which confirms our first claim.

Proof of Lemma 3

To see this, first note that:

- First, from Lemma 8, we already know that

$$\frac{d \sum_{j=0}^k p_{p_\alpha, j}^n}{dp_\alpha} = -n p_{p_\alpha, k}^{n-1} \quad (9)$$

- Equation 6 implies immediately:

$$\begin{aligned} \frac{d \sum_{j=0}^k p_{p_\alpha, j}^n j}{dp_\alpha} &= \sum_{j=0}^k n \{ p_{p_\alpha, j-1}^{n-1} - p_{p_\alpha, j}^{n-1} \} j \\ &= n \left[-k p_{p_\alpha, k}^{n-1} + \sum_{j=0}^{k-1} p_{p_\alpha, j}^{n-1} \right] \end{aligned} \quad (10)$$

- Note first that

$$\frac{dp_{p_\alpha, n}^n}{dp_\alpha} = np_\alpha^{n-1} = np_{p_\alpha, n-1}^{n-1}$$

Combine this with Equation 6 to see:

$$\begin{aligned} \frac{d \sum_{j=k+1}^n p_{p_\alpha, j}^n}{dp_\alpha} &= n \sum_{j=k+1}^{n-1} \{p_{p_\alpha, j-1}^{n-1} - p_{p_\alpha, j}^{n-1}\} j + n^2 p_{p_\alpha, n-1}^{n-1} \\ &= n[(k+1)p_{p_\alpha, k}^{n-1} + \sum_{j=k+1}^{n-1} p_{p_\alpha, j}^{n-1}] \end{aligned} \quad (11)$$

Combine Equations 9, 10 and 11 to see:

$$\begin{aligned} n^{-1} \frac{d\nabla_1^{na, a}}{dp_\alpha} &= \\ &D_c - D_{nc} + \Delta \\ &+ [b - \Delta] np_{p_\alpha, k}^{n-1} \\ &- [D_c - D_{nc} + \Delta] \left[\sum_{j=0}^{k-1} p_{p_\alpha, j}^{n-1} - kp_{p_\alpha, k}^{n-1} \right] \\ &- [D_c - D_{nc}] \left[(k+1)p_{p_\alpha, k}^{n-1} + \sum_{j=k+1}^{n-1} p_{p_\alpha, j}^{n-1} \right] \end{aligned}$$

Because $\sum_{j=0}^{k-1} p_{p_\alpha, j}^{n-1} + p_{p_\alpha, k}^{n-1} + \sum_{j=k+1}^{n-1} p_{p_\alpha, j}^{n-1} = 1$, we obtain:

$$\begin{aligned} n^{-1} \frac{d\nabla_1^{na, a}}{dp_\alpha} &= \\ &\Delta - \left\{ \sum_{j=0}^{k-1} p_{p_\alpha, j}^{n-1} \right\} \Delta + p_{p_\alpha, k}^{n-1} \{nb - (n-k)\Delta\} \end{aligned}$$

The definition of k implies $nb > (n-k-1)\Delta$ and thus (using $\sum_{j=0}^k p_{p_\alpha, j}^{n-1} = \sum_{j=0}^{k-1} p_{p_\alpha, j}^{n-1} + p_{p_\alpha, k}^{n-1}$):

$$\begin{aligned} n^{-1} \frac{d\nabla_1^{na, a}}{dp_\alpha} &> \\ &\Delta - \left\{ \sum_{j=0}^{k-1} p_{p_\alpha, j}^{n-1} \right\} \Delta - p_{p_\alpha, k}^{n-1} \Delta = \end{aligned}$$

$$(1 - \sum_{j=0}^k p_{p_\alpha, j}^{n-1})\Delta > 0$$

This confirms our second claim.

Proof of Lemma 4

If $p_\alpha = 1$, then: $\sum_{j=0}^k p_{p_\alpha, j}^n = \sum_{j=0}^k p_{p_\alpha, j}^n = 0$ and $\sum_{j=k+1}^n p_{p_\alpha, j}^n = n$. This implies immediately:

$$\nabla_2^{na, a}(p_\alpha = 1) = nD_c - a - nD_{nc} - [D_c - D_{nc}]n$$

which confirms our third claim.

Proof of Lemma 2

Following the same arguments as in the proof of Lemma 3, we can see:

$$\frac{d\nabla_2^{na, a}}{dp_\alpha} = -n\left\{\sum_{j=0}^{k-1} p_{p_\alpha, j}^{n-1}\Delta\right\} - np_{p_\alpha, k}^{n-1}\{-nb + (n-k)\Delta\}$$

The definition of k implies $nb < (n-k)\Delta$ and thus:

$$\frac{d\nabla_2^{na, a}}{dp_\alpha} < 0$$

B Proof of Lemma 15

First note that in this equilibrium, the probability of compliance is an increasing function of the fine.

Indeed, in equilibrium, the following equation is identically true:

$$\alpha - (\Psi + \gamma\alpha) \sum_{j=0}^k p_{p_\alpha, j}^{n-1} = 0$$

This implies that in equilibrium (differentiating for Ψ and using Lemma 8):

$$\begin{aligned} 0 &= -\sum_{j=0}^k p_{p_\alpha, j}^{n-1} - (\Psi + \gamma\alpha) \frac{d \sum_{j=0}^k p_{p_\alpha, j}^{n-1}}{dp_\alpha} \frac{dp_\alpha}{d\Psi} \\ &\Downarrow \\ \frac{dp_\alpha}{d\Psi} &= \frac{\sum_{j=0}^k p_{p_\alpha, j}^{n-1}}{(\Psi + \gamma\alpha)(n-1)p_{p_\alpha, k}^{n-2}} \\ &> 0 \end{aligned}$$

Thus, to proof this Lemma, we only need to show that $C_a^{k,n}(p_\alpha^*)$ is decreasing in p_α^* .

As in the proof of Lemma 3, combine Equations 9, 10 and 11 to see:

$$n^{-1} \frac{dC_a^{k,n}}{dp_\alpha} = D_c - D_{nc} + \left\{ \sum_{j=0}^{k-1} p_{p_\alpha, j}^{n-1} \right\} \Delta + p_{p_\alpha, k}^{n-1} \{-nb + (n-k)\Delta\}$$

The definition of k implies $nb > (n-k-1)\Delta$ and thus:

$$\begin{aligned} \frac{dC_a^{k,n}}{dp_\alpha} &< D_c - D_{nc} + \left\{ \sum_{j=0}^{k-1} p_{p_\alpha, j}^{n-1} \right\} \Delta + p_{p_\alpha, k}^{n-1} \Delta \\ &= D_c - D_{nc} + \left\{ \sum_{j=0}^k p_{p_\alpha, j}^{n-1} \right\} \Delta \end{aligned}$$

$\Delta < D_{nc} - D_c$ and $\sum_{j=0}^k p_{p_\alpha, j}^{n-1} < 1$ imply then that $\frac{dC_a^{k,n}}{dp_\alpha} < 0$. The chain rule for derivatives completes the proof. \square QED \square

Notes

¹I would like to thank Frans Spinnewyn in particular for suggesting this approach.

²The probability that these two technical parameters are equal is zero.

³In Becker's model (1968), the only effect of higher penalties is that they allow to reduce the probabilities of detection that are necessary to obtain a given level of compliance. If fines are a pure transfer, then they should indeed be as high as possible in order to save enforcement costs.

References

- G. Becker, 1968, Crime and punishment: An economic approach, *Journal of Political Economy*, 76, 169-180
- L. Franckx, 2002a, The use of ambient inspections in environmental monitoring and enforcement when the inspection agency cannot commit itself to announced inspection probabilities, *Journal of Environmental Economics and Management*, 43, 71-92
- L. Franckx, 2002b, Ambient environmental inspections and commitment towards enforcement policies: substitutes or complements?, *Topics in Economic Analysis & Policy: Vol. 2: No. 1, Article 1.*
- R.E. Grieson and N. Sing, 1990, Regulating externalities through testing, *Journal of Public Economics*, 41, pp. 369-387
- J.D. Harford, 1978, Firm behavior under imperfectly enforceable pollution standards and taxes, *Journal of Environmental Economics and Management*, 5, 26-43
- A.G. Keeler, 1991, Noncompliant Firms in Transferable Discharge Permit Market: Some Extensions, *Journal of Environmental Economics and Management*, 21, 180-189
- A.S. Malik, 1990, Market for Pollution Control when Firms Are Noncompliant, *Journal of Environmental Economics and Management*, 18, 97-106
- L. Martin, 1984, The optimal magnitude and enforcement of evadable Pigouvian taxes, *Public Finance*, 39, 347-358
- N. Melumad and D. Mookherjee, 1989, Delegation as Commitment: The Case of Income Tax Audits, *RAND Journal of Economics*, 20, pp.139-63
- D. Mookherjee and I.P.L. Png, 1992, Monitoring vis-à-vis Investigation in Enforcement of Law, *American Economic Review*, 82, 556-65
- C.S. Russel, W. Harrington and W.J. Vaughan, 1986, Enforcing pollution control laws, *Resources for the Future*, Washington, DC
- K. Segerson, 1988, Uncertainty and incentives for nonpoint pollution control, *Journal of Environmental Economics and Management*, 15, 87-98
- J.S. Shortle and D.G. Abler, 1997, Nonpoint pollution, in Folmer, H. and Tietenberg T. (ed.), *The International Yearbook of Environmental and Resource Economics 1997/1998*, Edward Elgar Publishing, Northampton, Massachusetts
- L. L. Wilde, 1992, Criminal Choice, Non-monetary Sanctions and Marginal Deterrence: A Normative Analysis, *International Review of Law and Economics*, 12, pp. 333-44
- A.P. Xepapadeas, 1999, Non-point source pollution control, in van den Bergh, J.C.J.M. (ed.), *Handbook of Environmental and Resource Economics*, Edward Elgar Publishing, Northampton, Massachusetts

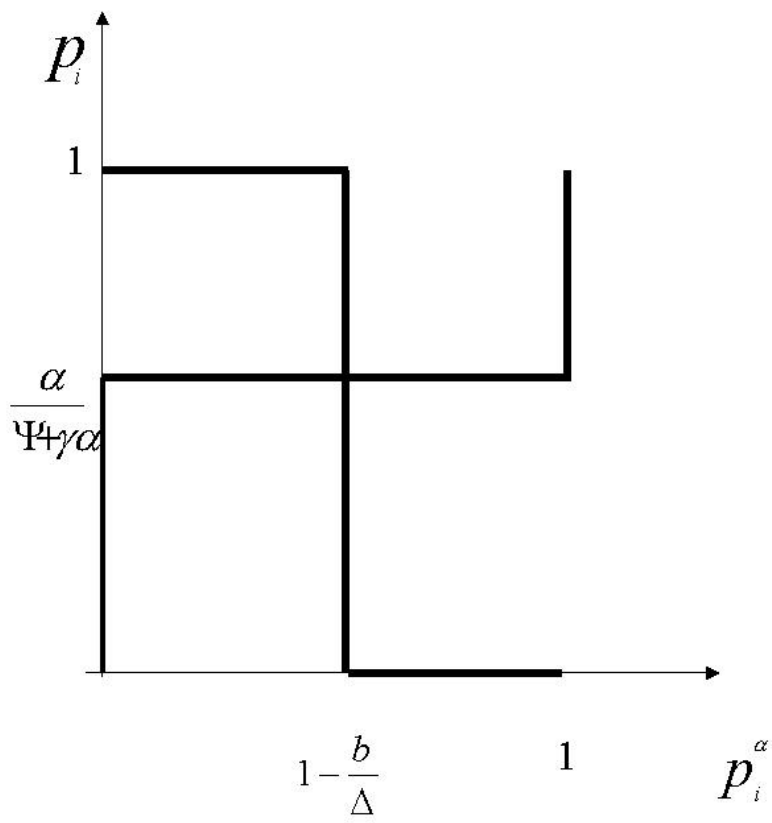


Figure 1: Reaction functions between firm i and the inspection agency without ambient inspections

NOTE DI LAVORO DELLA FONDAZIONE ENI ENRICO MATTEI

Fondazione Eni Enrico Mattei Working Papers Series

Our working papers are available on the Internet at the following addresses:

Server WWW: WWW.FEEM.IT

Anonymous FTP: FTP.FEEM.IT

http://papers.ssrn.com/abstract_id=XXXXXX

SUST	1.2001	<i>Inge MAYERES and Stef PROOST: <u>Should Diesel Cars in Europe be Discouraged?</u></i>
SUST	2.2001	<i>Paola DORIA and Davide PETTENELLA: <u>The Decision Making Process in Defining and Protecting Critical Natural Capital</u></i>
CLIM	3.2001	<i>Alberto PENCH: <u>Green Tax Reforms in a Computable General Equilibrium Model for Italy</u></i>
CLIM	4.2001	<i>Maurizio BUSSOLO and Dino PINELLI: <u>Green Taxes: Environment, Employment and Growth</u></i>
CLIM	5.2001	<i>Marco STAMPINI: <u>Tax Reforms and Environmental Policies for Italy</u></i>
ETA	6.2001	<i>Walid OUESLATI: <u>Environmental Fiscal Policy in an Endogenous Growth Model with Human Capital</u></i>
CLIM	7.2001	<i>Umberto CIORBA, Alessandro LANZA and Francesco PAULI: <u>Kyoto Commitment and Emission Trading: a European Union Perspective</u></i>
MGMT	8.2001	<i>Brian SLACK (xlv): <u>Globalisation in Maritime Transportation: Competition, uncertainty and implications for port development strategy</u></i>
VOL	9.2001	<i>Giulia PESARO: <u>Environmental Voluntary Agreements: A New Model of Co-operation Between Public and Economic Actors</u></i>
VOL	10.2001	<i>Cathrine HAGEM: <u>Climate Policy, Asymmetric Information and Firm Survival</u></i>
ETA	11.2001	<i>Sergio CURRARINI and Marco MARINI: <u>A Sequential Approach to the Characteristic Function and the Core in Games with Externalities</u></i>
ETA	12.2001	<i>Gaetano BLOISE, Sergio CURRARINI and Nicholas KIKIDIS: <u>Inflation and Welfare in an OLG Economy with a Privately Provided Public Good</u></i>
KNOW	13.2001	<i>Paolo SURICO: <u>Globalisation and Trade: A “New Economic Geography” Perspective</u></i>
ETA	14.2001	<i>Valentina BOSETTI and Vincenzina MESSINA: <u>Quasi Option Value and Irreversible Choices</u></i>
CLIM	15.2001	<i>Guy ENGELEN (xlii): <u>Desertification and Land Degradation in Mediterranean Areas: from Science to Integrated Policy Making</u></i>
SUST	16.2001	<i>Julie Catherine SORS: <u>Measuring Progress Towards Sustainable Development in Venice: A Comparative Assessment of Methods and Approaches</u></i>
SUST	17.2001	<i>Julie Catherine SORS: <u>Public Participation in Local Agenda 21: A Review of Traditional and Innovative Tools</u></i>
CLIM	18.2001	<i>Johan ALBRECHT and Niko GOBBIN: <u>Schumpeter and the Rise of Modern Environmentalism</u></i>
VOL	19.2001	<i>Rinaldo BRAU, Carlo CARRARO and Giulio GOLFETTO (xliii): <u>Participation Incentives and the Design of Voluntary Agreements</u></i>
ETA	20.2001	<i>Paola ROTA: <u>Dynamic Labour Demand with Lumpy and Kinked Adjustment Costs</u></i>
ETA	21.2001	<i>Paola ROTA: <u>Empirical Representation of Firms’ Employment Decisions by an (S,s) Rule</u></i>
ETA	22.2001	<i>Paola ROTA: <u>What Do We Gain by Being Discrete? An Introduction to the Econometrics of Discrete Decision Processes</u></i>
PRIV	23.2001	<i>Stefano BOSI, Guillaume GIRMANS and Michel GUILLARD: <u>Optimal Privatisation Design and Financial Markets</u></i>
KNOW	24.2001	<i>Giorgio BRUNELLO, Claudio LUPI, Patrizia ORDINE, and Maria Luisa PARISI: <u>Beyond National Institutions: Labour Taxes and Regional Unemployment in Italy</u></i>
ETA	25.2001	<i>Klaus CONRAD: <u>Locational Competition under Environmental Regulation when Input Prices and Productivity Differ</u></i>
PRIV	26.2001	<i>Bernardo BORTOLOTTI, Juliet D’SOUZA, Marcella FANTINI and William L. MEGGINSON: <u>Sources of Performance Improvement in Privatised Firms: A Clinical Study of the Global Telecommunications Industry</u></i>
CLIM	27.2001	<i>Frédéric BROCHIER and Emiliano RAMIERI: <u>Climate Change Impacts on the Mediterranean Coastal Zones</u></i>
ETA	28.2001	<i>Nunzio CAPPUCCIO and Michele MORETTO: <u>Comments on the Investment-Uncertainty Relationship in a Real Option Model</u></i>
KNOW	29.2001	<i>Giorgio BRUNELLO: <u>Absolute Risk Aversion and the Returns to Education</u></i>
CLIM	30.2001	<i>ZhongXiang ZHANG: <u>Meeting the Kyoto Targets: The Importance of Developing Country Participation</u></i>
ETA	31.2001	<i>Jonathan D. KAPLAN, Richard E. HOWITT and Y. Hossein FARZIN: <u>An Information-Theoretical Analysis of Budget-Constrained Nonpoint Source Pollution Control</u></i>
MGMT Coalition	32.2001	<i>Roberta SALOMONE and Giulia GALLUCCIO: <u>Environmental Issues and Financial Reporting Trends</u></i>
Theory Network	33.2001	<i>Shlomo WEBER and Hans WIESMETH: <u>From Autarky to Free Trade: The Impact on Environment</u></i>
ETA	34.2001	<i>Margarita GENIUS and Elisabetta STRAZZERA: <u>Model Selection and Tests for Non Nested Contingent Valuation Models: An Assessment of Methods</u></i>

NRM	35.2001	<i>Carlo GIUPPONI</i> : <u>The Substitution of Hazardous Molecules in Production Processes: The Atrazine Case Study in Italian Agriculture</u>
KNOW	36.2001	<i>Raffaele PACI and Francesco PIGLIARU</i> : <u>Technological Diffusion, Spatial Spillovers and Regional Convergence in Europe</u>
PRIV	37.2001	<i>Bernardo BORTOLOTTI</i> : <u>Privatisation, Large Shareholders, and Sequential Auctions of Shares</u>
CLIM	38.2001	<i>Barbara BUCHNER</i> : <u>What Really Happened in The Hague? Report on the COP6, Part I, 13-25 November 2000, The Hague, The Netherlands</u>
PRIV	39.2001	<i>Giacomo CALZOLARI and Carlo SCARPA</i> : <u>Regulation at Home, Competition Abroad: A Theoretical Framework</u>
KNOW	40.2001	<i>Giorgio BRUNELLO</i> : <u>On the Complementarity between Education and Training in Europe</u>
Coalition Theory Network	41.2001	<i>Alain DESDOIGTS and Fabien MOIZEAU</i> (xlvi): <u>Multiple Politico-Economic Regimes, Inequality and Growth</u>
Coalition Theory Network	42.2001	<i>Parkash CHANDER and Henry TULKENS</i> (xlvi): <u>Limits to Climate Change</u>
Coalition Theory Network	43.2001	<i>Michael FINUS and Bianca RUNDSHAGEN</i> (xlvi): <u>Endogenous Coalition Formation in Global Pollution Control</u>
Coalition Theory Network	44.2001	<i>Wietze LISE, Richard S.J. TOL and Bob van der ZWAAN</i> (xlvi): <u>Negotiating Climate Change as a Social Situation</u>
NRM	45.2001	<i>Mohamad R. KHAWLIE</i> (xlvi): <u>The Impacts of Climate Change on Water Resources of Lebanon- Eastern Mediterranean</u>
NRM	46.2001	<i>Mutasem EL-FADEL and E. BOU-ZEID</i> (xlvi): <u>Climate Change and Water Resources in the Middle East: Vulnerability, Socio-Economic Impacts and Adaptation</u>
NRM	47.2001	<i>Eva IGLESIAS, Alberto GARRIDO and Almudena GOMEZ</i> (xlvi): <u>An Economic Drought Management Index to Evaluate Water Institutions' Performance Under Uncertainty and Climate Change</u>
CLIM	48.2001	<i>Wietze LISE and Richard S.J. TOL</i> (xlvi): <u>Impact of Climate on Tourist Demand</u>
CLIM	49.2001	<i>Francesco BOSELLO, Barbara BUCHNER, Carlo CARRARO and Davide RAGGI</i> : <u>Can Equity Enhance Efficiency? Lessons from the Kyoto Protocol</u>
SUST	50.2001	<i>Roberto ROSON</i> (xlvi): <u>Carbon Leakage in a Small Open Economy with Capital Mobility</u>
SUST	51.2001	<i>Edwin WOERDMAN</i> (xlvi): <u>Developing a European Carbon Trading Market: Will Permit Allocation Distort Competition and Lead to State Aid?</u>
SUST	52.2001	<i>Richard N. COOPER</i> (xlvi): <u>The Kyoto Protocol: A Flawed Concept</u>
SUST	53.2001	<i>Kari KANGAS</i> (xlvi): <u>Trade Liberalisation, Changing Forest Management and Roundwood Trade in Europe</u>
SUST	54.2001	<i>Xueqin ZHU and Ekko VAN IERLAND</i> (xlvi): <u>Effects of the Enlargement of EU on Trade and the Environment</u>
SUST	55.2001	<i>M. Ozgur KAYALICA and Sajal LAHIRI</i> (xlvi): <u>Strategic Environmental Policies in the Presence of Foreign Direct Investment</u>
SUST	56.2001	<i>Savas ALPAY</i> (xlvi): <u>Can Environmental Regulations be Compatible with Higher International Competitiveness? Some New Theoretical Insights</u>
SUST	57.2001	<i>Roldan MURADIAN, Martin O'CONNOR, Joan MARTINEZ-ALER</i> (xlvi): <u>Embodied Pollution in Trade: Estimating the "Environmental Load Displacement" of Industrialised Countries</u>
SUST	58.2001	<i>Matthew R. AUER and Rafael REUVENY</i> (xlvi): <u>Foreign Aid and Direct Investment: Key Players in the Environmental Restoration of Central and Eastern Europe</u>
SUST	59.2001	<i>Onno J. KUIK and Frans H. OOSTERHUIS</i> (xlvi): <u>Lessons from the Southern Enlargement of the EU for the Environmental Dimensions of Eastern Enlargement, in particular for Poland</u>
ETA	60.2001	<i>Carlo CARRARO, Alessandra POME and Domenico SINISCALCO</i> (xlix): <u>Science vs. Profit in Research: Lessons from the Human Genome Project</u>
CLIM	61.2001	<i>Efrem CASTELNUOVO, Michele MORETTO and Sergio VERGALLI</i> : <u>Global Warming, Uncertainty and Endogenous Technical Change: Implications for Kyoto</u>
PRIV	62.2001	<i>Gian Luigi ALBANO, Fabrizio GERMANO and Stefano LOVO</i> : <u>On Some Collusive and Signaling Equilibria in Ascending Auctions for Multiple Objects</u>
CLIM	63.2001	<i>Elbert DIJKGRAAF and Herman R.J. VOLLEBERGH</i> : <u>A Note on Testing for Environmental Kuznets Curves with Panel Data</u>
CLIM	64.2001	<i>Paolo BUONANNO, Carlo CARRARO and Marzio GALEOTTI</i> : <u>Endogenous Induced Technical Change and the Costs of Kyoto</u>
CLIM	65.2001	<i>Guido CAZZAVILLAN and Ignazio MUSU</i> (l): <u>Transitional Dynamics and Uniqueness of the Balanced-Growth Path in a Simple Model of Endogenous Growth with an Environmental Asset</u>
CLIM	66.2001	<i>Giovanni BAIOCCHI and Salvatore DI FALCO</i> (l): <u>Investigating the Shape of the EKC: A Nonparametric Approach</u>
CLIM	67.2001	<i>Marzio GALEOTTI, Alessandro LANZA and Francesco PAULI</i> (l): <u>Desperately Seeking (Environmental) Kuznets: A New Look at the Evidence</u>
CLIM	68.2001	<i>Alexey VIKHLYAEV</i> (xlvi): <u>The Use of Trade Measures for Environmental Purposes – Globally and in the EU Context</u>
NRM	69.2001	<i>Gary D. LIBECAP and Zeynep K. HANSEN</i> (li): <u>U.S. Land Policy, Property Rights, and the Dust Bowl of the 1930s</u>

NRM	70.2001	<i>Lee J. ALSTON, Gary D. LIBECAP and Bernardo MUELLER</i> (li): <u>Land Reform Policies. The Sources of Violent Conflict and Implications for Deforestation in the Brazilian Amazon</u>
CLIM	71.2001	<i>Claudia KEMFERT</i> : <u>Economy-Energy-Climate Interaction – The Model WIAGEM -</u>
SUST	72.2001	<i>Paulo A.L.D. NUNES and Yohanes E. RIYANTO</i> : <u>Policy Instruments for Creating Markets for Biodiversity: Certification and Ecolabeling</u>
SUST	73.2001	<i>Paulo A.L.D. NUNES and Erik SCHOKKAERT</i> (lii): <u>Warm Glow and Embedding in Contingent Valuation</u>
SUST	74.2001	<i>Paulo A.L.D. NUNES, Jeroen C.J.M. van den BERGH and Peter NIJKAMP</i> (lii): <u>Ecological-Economic Analysis and Valuation of Biodiversity</u>
VOL	75.2001	<i>Johan EYCKMANS and Henry TULKENS</i> (li): <u>Simulating Coalitionally Stable Burden Sharing Agreements for the Climate Change Problem</u>
PRIV	76.2001	<i>Axel GAUTIER and Florian HEIDER</i> : <u>What Do Internal Capital Markets Do? Redistribution vs. Incentives</u>
PRIV	77.2001	<i>Bernardo BORTOLOTTI, Marcella FANTINI and Domenico SINISCALCO</i> : <u>Privatisation around the World: New Evidence from Panel Data</u>
ETA	78.2001	<i>Toke S. AIDT and Jayasri DUTTA</i> (li): <u>Transitional Politics. Emerging Incentive-based Instruments in Environmental Regulation</u>
ETA	79.2001	<i>Alberto PETRUCCI</i> : <u>Consumption Taxation and Endogenous Growth in a Model with New Generations</u>
ETA	80.2001	<i>Pierre LASSERRE and Antoine SOUBEYRAN</i> (li): <u>A Ricardian Model of the Tragedy of the Commons</u>
ETA	81.2001	<i>Pierre COURTOIS, Jean Christophe PÉREAU and Tarik TAZDAÏT</i> : <u>An Evolutionary Approach to the Climate Change Negotiation Game</u>
NRM	82.2001	<i>Christophe BONTEMPS, Stéphane COUTURE and Pascal FAVARD</i> : <u>Is the Irrigation Water Demand Really Convex?</u>
NRM	83.2001	<i>Unai PASCUAL and Edward BARBIER</i> : <u>A Model of Optimal Labour and Soil Use with Shifting Cultivation</u>
CLIM	84.2001	<i>Jesper JENSEN and Martin Hvidt THELLE</i> : <u>What are the Gains from a Multi-Gas Strategy?</u>
CLIM	85.2001	<i>Maurizio MICHELINI</i> (liii): IPCC “Summary for Policymakers” in TAR. <u>Do its results give a scientific support always adequate to the urgencies of Kyoto negotiations?</u>
CLIM	86.2001	<i>Claudia KEMFERT</i> (liii): <u>Economic Impact Assessment of Alternative Climate Policy Strategies</u>
CLIM	87.2001	<i>Cesare DOSI and Michele MORETTO</i> : <u>Global Warming and Financial Umbrellas</u>
ETA	88.2001	<i>Elena BONTEMPI, Alessandra DEL BOCA, Alessandra FRANZOSI, Marzio GALEOTTI and Paola ROTA</i> : <u>Capital Heterogeneity: Does it Matter? Fundamental Q and Investment on a Panel of Italian Firms</u>
ETA	89.2001	<i>Efrem CASTELNUOVO and Paolo SURICO</i> : <u>Model Uncertainty, Optimal Monetary Policy and the Preferences of the Fed</u>
CLIM	90.2001	<i>Umberto CIORBA, Alessandro LANZA and Francesco PAULI</i> : <u>Kyoto Protocol and Emission Trading: Does the US Make a Difference?</u>
CLIM	91.2001	<i>ZhongXiang ZHANG and Lucas ASSUNCAO</i> : <u>Domestic Climate Policies and the WTO</u>
SUST	92.2001	<i>Anna ALBERINI, Alan KRUPNICK, Maureen CROPPER, Nathalie SIMON and Joseph COOK</i> (lii): <u>The Willingness to Pay for Mortality Risk Reductions: A Comparison of the United States and Canada</u>
SUST	93.2001	<i>Riccardo SCARPA, Guy D. GARROD and Kenneth G. WILLIS</i> (lii): <u>Valuing Local Public Goods with Advanced Stated Preference Models: Traffic Calming Schemes in Northern England</u>
CLIM	94.2001	<i>Ming CHEN and Larry KARP</i> : <u>Environmental Indices for the Chinese Grain Sector</u>
CLIM	95.2001	<i>Larry KARP and Jiangfeng ZHANG</i> : <u>Controlling a Stock Pollutant with Endogenous Investment and Asymmetric Information</u>
ETA	96.2001	<i>Michele MORETTO and Gianpaolo ROSSINI</i> : <u>On the Opportunity Cost of Nontradable Stock Options</u>
SUST	97.2001	<i>Elisabetta STRAZZERA, Margarita GENIUS, Riccardo SCARPA and George HUTCHINSON</i> : <u>The Effect of Protest Votes on the Estimates of Willingness to Pay for Use Values of Recreational Sites</u>
NRM	98.2001	<i>Frédéric BROCHIER, Carlo GIUPPONI and Alberto LONGO</i> : <u>Integrated Coastal Zone Management in the Venice Area – Perspectives of Development for the Rural Island of Sant’Erasmus</u>
NRM	99.2001	<i>Frédéric BROCHIER, Carlo GIUPPONI and Julie SORS</i> : <u>Integrated Coastal Management in the Venice Area – Potentials of the Integrated Participatory Management Approach</u>
NRM	100.2001	<i>Frédéric BROCHIER and Carlo GIUPPONI</i> : <u>Integrated Coastal Zone Management in the Venice Area – A Methodological Framework</u>
PRIV	101.2001	<i>Enrico C. PEROTTI and Luc LAEVEN</i> : <u>Confidence Building in Emerging Stock Markets</u>
CLIM	102.2001	<i>Barbara BUCHNER, Carlo CARRARO and Igor CERSOSIMO</i> : <u>On the Consequences of the U.S. Withdrawal from the Kyoto/Bonn Protocol</u>
SUST	103.2001	<i>Riccardo SCARPA, Adam DRUCKER, Simon ANDERSON, Nancy FERRAES-EHUAN, Veronica GOMEZ, Carlos R. RISOPATRON and Olga RUBIO-LEONEL</i> : <u>Valuing Animal Genetic Resources in Peasant Economies: The Case of the Box Keken Creole Pig in Yucatan</u>
SUST	104.2001	<i>R. SCARPA, P. KRISTJANSON, A. DRUCKER, M. RADENY, E.S.K. RUTO, and J.E.O. REGE</i> : <u>Valuing Indigenous Cattle Breeds in Kenya: An Empirical Comparison of Stated and Revealed Preference Value Estimates</u>
SUST	105.2001	<i>Clemens B.A. WOLLNY</i> : <u>The Need to Conserve Farm Animal Genetic Resources Through Community-Based Management in Africa: Should Policy Makers be Concerned?</u>
SUST	106.2001	<i>J.T. KARUGIA, O.A. MWAI, R. KAITHO, Adam G. DRUCKER, C.B.A. WOLLNY and J.E.O. REGE</i> : <u>Economic Analysis of Crossbreeding Programmes in Sub-Saharan Africa: A Conceptual Framework and Kenyan Case Study</u>
SUST	107.2001	<i>W. AYALEW, J.M. KING, E. BRUNS and B. RISCHKOWSKY</i> : <u>Economic Evaluation of Smallholder Subsistence Livestock Production: Lessons from an Ethiopian Goat Development Program</u>

SUST	108.2001	<i>Gianni CICIA, Elisabetta D'ERCOLE and Davide MARINO: <u>Valuing Farm Animal Genetic Resources by Means of Contingent Valuation and a Bio-Economic Model: The Case of the Pentro Horse</u></i>
SUST	109.2001	<i>Clem TISDELL: <u>Socioeconomic Causes of Loss of Animal Genetic Diversity: Analysis and Assessment</u></i>
SUST	110.2001	<i>M.A. JABBAR and M.L. DIEDHOU: <u>Does Breed Matter to Cattle Farmers and Buyers? Evidence from West Africa</u></i>
SUST	1.2002	<i>K. TANO, M.D. FAMINOW, M. KAMUANGA and B. SWALLOW: <u>Using Conjoint Analysis to Estimate Farmers' Preferences for Cattle Traits in West Africa</u></i>
ETA	2.2002	<i>Efrem CASTELNUOVO and Paolo SURICO: <u>What Does Monetary Policy Reveal about Central Bank's Preferences?</u></i>
WAT	3.2002	<i>Duncan KNOWLER and Edward BARBIER: <u>The Economics of a "Mixed Blessing" Effect: A Case Study of the Black Sea</u></i>
CLIM	4.2002	<i>Andreas LÖSCHEL: <u>Technological Change in Economic Models of Environmental Policy: A Survey</u></i>
VOL	5.2002	<i>Carlo CARRARO and Carmen MARCHIORI: <u>Stable Coalitions</u></i>
CLIM	6.2002	<i>Marzio GALEOTTI, Alessandro LANZA and Matteo MANERA: <u>Rockets and Feathers Revisited: An International Comparison on European Gasoline Markets</u></i>
ETA	7.2002	<i>Effrosyni DIAMANTOUDI and Eftichios S. SARTZETAKIS: <u>Stable International Environmental Agreements: An Analytical Approach</u></i>
KNOW	8.2002	<i>Alain DESDOIGTS: <u>Neoclassical Convergence Versus Technological Catch-up: A Contribution for Reaching a Consensus</u></i>
NRM	9.2002	<i>Giuseppe DI VITA: <u>Renewable Resources and Waste Recycling</u></i>
KNOW	10.2002	<i>Giorgio BRUNELLO: <u>Is Training More Frequent when Wage Compression is Higher? Evidence from 11 European Countries</u></i>
ETA	11.2002	<i>Mordecai KURZ, Hehui JIN and Maurizio MOTOLESE: <u>Endogenous Fluctuations and the Role of Monetary Policy</u></i>
KNOW	12.2002	<i>Reyer GERLAGH and Marjan W. HOFKES: <u>Escaping Lock-in: The Scope for a Transition towards Sustainable Growth?</u></i>
NRM	13.2002	<i>Michele MORETTO and Paolo ROSATO: <u>The Use of Common Property Resources: A Dynamic Model</u></i>
CLIM	14.2002	<i>Philippe QUIRION: <u>Macroeconomic Effects of an Energy Saving Policy in the Public Sector</u></i>
CLIM	15.2002	<i>Roberto ROSON: <u>Dynamic and Distributional Effects of Environmental Revenue Recycling Schemes: Simulations with a General Equilibrium Model of the Italian Economy</u></i>
CLIM	16.2002	<i>Francesco RICCI (I): <u>Environmental Policy Growth when Inputs are Differentiated in Pollution Intensity</u></i>
ETA	17.2002	<i>Alberto PETRUCCI: <u>Devaluation (Levels versus Rates) and Balance of Payments in a Cash-in-Advance Economy</u></i>
Coalition Theory Network	18.2002	<i>László Á. KÓCZY (liv): <u>The Core in the Presence of Externalities</u></i>
Coalition Theory Network	19.2002	<i>Steven J. BRAMS, Michael A. JONES and D. Marc KILGOUR (liv): <u>Single-Peakedness and Disconnected Coalitions</u></i>
Coalition Theory Network	20.2002	<i>Guillaume HAERINGER (liv): <u>On the Stability of Cooperation Structures</u></i>
NRM	21.2002	<i>Fausto CAVALLARO and Luigi CIRAULO: <u>Economic and Environmental Sustainability: A Dynamic Approach in Insular Systems</u></i>
CLIM	22.2002	<i>Barbara BUCHNER, Carlo CARRARO, Igor CERSOSIMO and Carmen MARCHIORI: <u>Back to Kyoto? US Participation and the Linkage between R&D and Climate Cooperation</u></i>
CLIM	23.2002	<i>Andreas LÖSCHEL and ZhongXIANG ZHANG: <u>The Economic and Environmental Implications of the US Repudiation of the Kyoto Protocol and the Subsequent Deals in Bonn and Marrakech</u></i>
ETA	24.2002	<i>Marzio GALEOTTI, Louis J. MACCINI and Fabio SCHIANTARELLI: <u>Inventories, Employment and Hours</u></i>
CLIM	25.2002	<i>Hannes EGLI: <u>Are Cross-Country Studies of the Environmental Kuznets Curve Misleading? New Evidence from Time Series Data for Germany</u></i>
ETA	26.2002	<i>Adam B. JAFFE, Richard G. NEWELL and Robert N. STAVINS: <u>Environmental Policy and Technological Change</u></i>
SUST	27.2002	<i>Joseph C. COOPER and Giovanni SIGNORELLO: <u>Farmer Premiums for the Voluntary Adoption of Conservation Plans</u></i>
SUST	28.2002	<i><u>The ANSEA Network: Towards An Analytical Strategic Environmental Assessment</u></i>
KNOW	29.2002	<i>Paolo SURICO: <u>Geographic Concentration and Increasing Returns: a Survey of Evidence</u></i>
ETA	30.2002	<i>Robert N. STAVINS: <u>Lessons from the American Experiment with Market-Based Environmental Policies</u></i>
NRM	31.2002	<i>Carlo GIUPPONI and Paolo ROSATO: <u>Multi-Criteria Analysis and Decision-Support for Water Management at the Catchment Scale: An Application to Diffuse Pollution Control in the Venice Lagoon</u></i>
NRM	32.2002	<i>Robert N. STAVINS: <u>National Environmental Policy During the Clinton Years</u></i>
KNOW	33.2002	<i>A. SOUBEYRAN and H. STAHN : <u>Do Investments in Specialized Knowledge Lead to Composite Good Industries?</u></i>
KNOW	34.2002	<i>G. BRUNELLO, M.L. PARISI and Daniela SONEDDA: <u>Labor Taxes, Wage Setting and the Relative Wage Effect</u></i>
CLIM	35.2002	<i>C. BOEMARE and P. QUIRION (lv): <u>Implementing Greenhouse Gas Trading in Europe: Lessons from Economic Theory and International Experiences</u></i>

CLIM	36.2002	<i>T. TIETENBERG</i> (lv): <u>The Tradable Permits Approach to Protecting the Commons: What Have We Learned?</u>
CLIM	37.2002	<i>K. REHDANZ and R.J.S. TOL</i> (lv): <u>On National and International Trade in Greenhouse Gas Emission Permits</u>
CLIM	38.2002	<i>C. FISCHER</i> (lv): <u>Multinational Taxation and International Emissions Trading</u>
SUST	39.2002	<i>G. SIGNORELLO and G. PAPPALARDO</i> : <u>Farm Animal Biodiversity Conservation Activities in Europe under the Framework of Agenda 2000</u>
NRM	40.2002	<i>S.M. CAVANAGH, W. M. HANEMANN and R. N. STAVINS</i> : <u>Muffled Price Signals: Household Water Demand under Increasing-Block Prices</u>
NRM	41.2002	<i>A. J. PLANTINGA, R. N. LUBOWSKI and R. N. STAVINS</i> : <u>The Effects of Potential Land Development on Agricultural Land Prices</u>
CLIM	42.2002	<i>C. OHL</i> (lvi): <u>Inducing Environmental Co-operation by the Design of Emission Permits</u>
CLIM	43.2002	<i>J. EYCKMANS, D. VAN REGEMORTER and V. VAN STEENBERGHE</i> (lvi): <u>Is Kyoto Fatally Flawed? An Analysis with MacGEM</u>
CLIM	44.2002	<i>A. ANTOCI and S. BORGHESI</i> (lvi): <u>Working Too Much in a Polluted World: A North-South Evolutionary Model</u>
ETA	45.2002	<i>P. G. FREDRIKSSON, Johan A. LIST and Daniel MILLIMET</i> (lvi): <u>Chasing the Smokestack: Strategic Policymaking with Multiple Instruments</u>
ETA	46.2002	<i>Z. YU</i> (lvi): <u>A Theory of Strategic Vertical DFI and the Missing Pollution-Haven Effect</u>
SUST	47.2002	<i>Y. H. FARZIN</i> : <u>Can an Exhaustible Resource Economy Be Sustainable?</u>
SUST	48.2002	<i>Y. H. FARZIN</i> : <u>Sustainability and Hamiltonian Value</u>
KNOW	49.2002	<i>C. PIGA and M. VIVARELLI</i> : <u>Cooperation in R&D and Sample Selection</u>
Coalition Theory Network Coalition Theory Network	50.2002	<i>M. SERTEL and A. SLINKO</i> (liv): <u>Ranking Committees, Words or Multisets</u>
ETA	51.2002	<i>Sergio CURRARINI</i> (liv): <u>Stable Organizations with Externalities</u>
ETA	52.2002	<i>Robert N. STAVINS</i> : <u>Experience with Market-Based Policy Instruments</u>
ETA	53.2002	<i>C.C. JAEGER, M. LEIMBACH, C. CARRARO, K. HASSELMANN, J.C. HOURCADE, A. KEELER and R. KLEIN</i> (liii): <u>Integrated Assessment Modeling: Modules for Cooperation</u>
CLIM	54.2002	<i>Scott BARRETT</i> (liii): <u>Towards a Better Climate Treaty</u>
ETA	55.2002	<i>Richard G. NEWELL and Robert N. STAVINS</i> : <u>Cost Heterogeneity and the Potential Savings from Market-Based Policies</u>
SUST	56.2002	<i>Paolo ROSATO and Edi DEFRANCESCO</i> : <u>Individual Travel Cost Method and Flow Fixed Costs</u>
SUST	57.2002	<i>Vladimir KOTOV and Elena NIKITINA</i> (lvii): <u>Reorganisation of Environmental Policy in Russia: The Decade of Success and Failures in Implementation of Perspective Quests</u>
SUST	58.2002	<i>Vladimir KOTOV</i> (lvii): <u>Policy in Transition: New Framework for Russia's Climate Policy</u>
SUST	59.2002	<i>Fanny MISSFELDT and Arturo VILLAVICENCO</i> (lvii): <u>How Can Economies in Transition Pursue Emissions Trading or Joint Implementation?</u>
VOL	60.2002	<i>Giovanni DI BARTOLOMEO, Jacob ENGWERDA, Joseph PLASMANS and Bas VAN AARLE</i> : <u>Staying Together or Breaking Apart: Policy-Makers' Endogenous Coalitions Formation in the European Economic and Monetary Union</u>
ETA	61.2002	<i>Robert N. STAVINS, Alexander F. WAGNER and Gernot WAGNER</i> : <u>Interpreting Sustainability in Economic Terms: Dynamic Efficiency Plus Intergenerational Equity</u>
PRIV	62.2002	<i>Carlo CAPUANO</i> : <u>Demand Growth, Entry and Collusion Sustainability</u>
PRIV	63.2002	<i>Federico MUNARI and Raffaele ORIANI</i> : <u>Privatization and R&D Performance: An Empirical Analysis Based on Tobin's Q</u>
PRIV	64.2002	<i>Federico MUNARI and Maurizio SOBRERO</i> : <u>The Effects of Privatization on R&D Investments and Patent Productivity</u>
SUST	65.2002	<i>Orley ASHENFELTER and Michael GREENSTONE</i> : <u>Using Mandated Speed Limits to Measure the Value of a Statistical Life</u>
ETA	66.2002	<i>Paolo SURICO</i> : <u>US Monetary Policy Rules: the Case for Asymmetric Preferences</u>
PRIV	67.2002	<i>Rinaldo BRAU and Massimo FLORIO</i> : <u>Privatisations as Price Reforms: Evaluating Consumers' Welfare Changes in the U.K.</u>
CLIM	68.2002	<i>Barbara K. BUCHNER and Roberto ROSON</i> : <u>Conflicting Perspectives in Trade and Environmental Negotiations</u>
CLIM	69.2002	<i>Philippe QUIRION</i> : <u>Complying with the Kyoto Protocol under Uncertainty: Taxes or Tradable Permits?</u>
SUST	70.2002	<i>Anna ALBERINI, Patrizia RIGANTI and Alberto LONGO</i> : <u>Can People Value the Aesthetic and Use Services of Urban Sites? Evidence from a Survey of Belfast Residents</u>
SUST	71.2002	<i>Marco PERCOCO</i> : <u>Discounting Environmental Effects in Project Appraisal</u>
NRM	72.2002	<i>Philippe BONTEMS and Pascal FAVARD</i> : <u>Input Use and Capacity Constraint under Uncertainty: The Case of Irrigation</u>
PRIV	73.2002	<i>Mohammed OMRAN</i> : <u>The Performance of State-Owned Enterprises and Newly Privatized Firms: Empirical Evidence from Egypt</u>
PRIV	74.2002	<i>Mike BURKART, Fausto PANUNZI and Andrei SHLEIFER</i> : <u>Family Firms</u>
PRIV	75.2002	<i>Emmanuelle AURIOL, Pierre M. PICARD</i> : <u>Privatizations in Developing Countries and the Government Budget Constraint</u>
PRIV	76.2002	<i>Nichole M. CASTATER</i> : <u>Privatization as a Means to Societal Transformation: An Empirical Study of Privatization in Central and Eastern Europe and the Former Soviet Union</u>

PRIV	77.2002	<i>Christoph LÜLSFESMANN</i> : <u>Benevolent Government, Managerial Incentives, and the Virtues of Privatization</u>
PRIV	78.2002	<i>Kate BISHOP, Igor FILATOTCHEV and Tomasz MICKIEWICZ</i> : <u>Endogenous Ownership Structure: Factors Affecting the Post-Privatisation Equity in Largest Hungarian Firms</u>
PRIV	79.2002	<i>Theodora WELCH and Rick MOLZ</i> : <u>How Does Trade Sale Privatization Work? Evidence from the Fixed-Line Telecommunications Sector in Developing Economies</u>
PRIV	80.2002	<i>Alberto R. PETRUCCI</i> : <u>Government Debt, Agent Heterogeneity and Wealth Displacement in a Small Open Economy</u>
CLIM	81.2002	<i>Timothy SWANSON and Robin MASON</i> (lvi): <u>The Impact of International Environmental Agreements: The Case of the Montreal Protocol</u>
PRIV	82.2002	<i>George R.G. CLARKE and Lixin Colin XU</i> : <u>Privatization, Competition and Corruption: How Characteristics of Bribe Takers and Payers Affect Bribe Payments to Utilities</u>
PRIV	83.2002	<i>Massimo FLORIO and Katuscia MANZONI</i> : <u>The Abnormal Returns of UK Privatisations: From Underpricing to Outperformance</u>
NRM	84.2002	<i>Nelson LOURENÇO, Carlos RUSSO MACHADO, Maria do ROSÁRIO JORGE and Luís RODRIGUES</i> : <u>An Integrated Approach to Understand Territory Dynamics. The Coastal Alentejo (Portugal)</u>
CLIM	85.2002	<i>Peter ZAPFEL and Matti VAINIO</i> (lv): <u>Pathways to European Greenhouse Gas Emissions Trading History and Misconceptions</u>
CLIM	86.2002	<i>Pierre COURTOIS</i> : <u>Influence Processes in Climate Change Negotiations: Modelling the Rounds</u>
ETA	87.2002	<i>Vito FRAGNELLI and Maria Erminia MARINA</i> (lviii): <u>Environmental Pollution Risk and Insurance</u>
ETA	88.2002	<i>Laurent FRANCKX</i> (lviii): <u>Environmental Enforcement with Endogenous Ambient Monitoring</u>

(xlii) This paper was presented at the International Workshop on "Climate Change and Mediterranean Coastal Systems: Regional Scenarios and Vulnerability Assessment" organised by the Fondazione Eni Enrico Mattei in co-operation with the Istituto Veneto di Scienze, Lettere ed Arti, Venice, December 9-10, 1999.

(xliii) This paper was presented at the International Workshop on "Voluntary Approaches, Competition and Competitiveness" organised by the Fondazione Eni Enrico Mattei within the research activities of the CAVA Network, Milan, May 25-26, 2000.

(xliv) This paper was presented at the International Workshop on "Green National Accounting in Europe: Comparison of Methods and Experiences" organised by the Fondazione Eni Enrico Mattei within the Concerted Action of Environmental Valuation in Europe (EVE), Milan, March 4-7, 2000

(xlv) This paper was presented at the International Workshop on "New Ports and Urban and Regional Development. The Dynamics of Sustainability" organised by the Fondazione Eni Enrico Mattei, Venice, May 5-6, 2000.

(xlvi) This paper was presented at the Sixth Meeting of the Coalition Theory Network organised by the Fondazione Eni Enrico Mattei and the CORE, Université Catholique de Louvain, Louvain-la-Neuve, Belgium, January 26-27, 2001

(xlvii) This paper was presented at the RICAMARE Workshop "Socioeconomic Assessments of Climate Change in the Mediterranean: Impact, Adaptation and Mitigation Co-benefits", organised by the Fondazione Eni Enrico Mattei, Milan, February 9-10, 2001

(xlviii) This paper was presented at the International Workshop "Trade and the Environment in the Perspective of the EU Enlargement", organised by the Fondazione Eni Enrico Mattei, Milan, May 17-18, 2001

(xlix) This paper was presented at the International Conference "Knowledge as an Economic Good", organised by Fondazione Eni Enrico Mattei and The Beijer International Institute of Environmental Economics, Palermo, April 20-21, 2001

(l) This paper was presented at the Workshop "Growth, Environmental Policies and Sustainability" organised by the Fondazione Eni Enrico Mattei, Venice, June 1, 2001

(li) This paper was presented at the Fourth Toulouse Conference on Environment and Resource Economics on "Property Rights, Institutions and Management of Environmental and Natural Resources", organised by Fondazione Eni Enrico Mattei, IDEI and INRA and sponsored by MATE, Toulouse, May 3-4, 2001

(lii) This paper was presented at the International Conference on "Economic Valuation of Environmental Goods", organised by Fondazione Eni Enrico Mattei in cooperation with CORILA, Venice, May 11, 2001

(liii) This paper was circulated at the International Conference on "Climate Policy – Do We Need a New Approach?", jointly organised by Fondazione Eni Enrico Mattei, Stanford University and Venice International University, Isola di San Servolo, Venice, September 6-8, 2001

(liv) This paper was presented at the Seventh Meeting of the Coalition Theory Network organised by the Fondazione Eni Enrico Mattei and the CORE, Université Catholique de Louvain, Venice, Italy, January 11-12, 2002

(lv) This paper was presented at the First Workshop of the Concerted Action on Tradable Emission Permits (CATEP) organised by the Fondazione Eni Enrico Mattei, Venice, Italy, December 3-4, 2001

(lvi) This paper was presented at the ESF EURESCO Conference on Environmental Policy in a Global Economy "The International Dimension of Environmental Policy", organised with the collaboration of the Fondazione Eni Enrico Mattei, Acquafredda di Maratea, October 6-11, 2001

(lvii) This paper was presented at the First Workshop of "CFEWE – Carbon Flows between Eastern and Western Europe", organised by the Fondazione Eni Enrico Mattei and Zentrum für Europäische Integrationsforschung (ZEI), Milan, July 5-6, 2001

(lviii) This paper was presented at the Workshop on "Game Practice and the Environment", jointly organised by Università del Piemonte Orientale and Fondazione Eni Enrico Mattei, Alessandria, April 12-13, 2002

2002 SERIES

CLIM *Climate Change Modelling and Policy* (Editor: Marzio Galeotti)

VOL *Voluntary and International Agreements* (Editor: Carlo Carraro)

SUST *Sustainability Indicators and Environmental Evaluation*
(Editor: Carlo Carraro)

NRM *Natural Resources Management* (Editor: Carlo Giupponi)

KNOW *Knowledge, Technology, Human Capital* (Editor: Dino Pinelli)

MGMT *Corporate Sustainable Management* (Editor: Andrea Marsanich)

PRIV *Privatisation, Regulation, Antitrust* (Editor: Bernardo Bortolotti)

ETA *Economic Theory and Applications* (Editor: Carlo Carraro)