Economics of integrated pollution prevention policies: introductory remarks

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**Abstract**

The European directive on integrated pollution prevention and control (IPPC, council directive 96/61/EC) sets new approaches to authorization for large sources of pollution. The core of IPPC refers to technology-related emission limits (EL); the technology considered in order to establish EL can be BAT (Best Available Techniques), BATNEEC (Best Available Techniques Not Entailing Excessive Cost) or BEA (Best Environmental Practices). The paper focuses on a model of a firm's behaviour in the context of traditional or integrated standards, showing how IPPC hinders cross-ambient-pollution-transfer pushing firms to the higher cost frontiers of environmental protection.

**1 Introduction**

**1.1 The standards in environmental policies**

As known, standards are strange animals in the environmental economics: in theory, they should not exist because are inefficient, in practice they proliferate. It seems a common rule for microeconomics that things that are not optimal in models happen to be the most common in the real world, in which we can find two main families of instruments, outlined in the following paragraphs.

**1.1.1 Environmental Quality Standards**

Environmental quality (EQ) standards (the environment must not be polluted more than...). The rationale of quality standards is the fact that exposure of individuals, vegetables and things to bad environmental conditions can cause damages. Therefore governments announce minimum quality conditions for air, water, groundwater, soil, level of noise or heat, vibrations, electromagnetic...
emissions and so on. The level of EQ is, in effect, the real aim of environmental policies: instruments to reach the goals can be different, from emission standards to taxes or markets of emissions.

1.1.2 Emissions Standards

Emission Standards (ES) (you must not pollute more than...). Emission limits are prescribed for single emission sources. They can be expressed in terms of concentration in effluents (CBEL) or mass-related (MBEL). Lower levels of emissions from specific sources can be obtained also by Technical Standards (TS) (you must adopt this device/process/fuel...): as a regulatory approach, TS (3) are strictly related to emission limits because they are supposed to achieve lower emissions through better materials or techniques. In the following paragraphs "standard" and "limit" are used as synonymous.

1.2 Integrated standards

1.2.1 The IPPC directive

The directive on integrated pollution prevention and control (4) contains a melting of the two approaches outlined in the previous paragraph and represents, for the environmental policy, a main step forward. The strongest hint of the integrated approach is represented by "integrated permits" for the bigger sources of pollution, with mass-based-emission-limits (MBEL) that hit the production process at the core forcing firms to adopt the best available techniques (BAT).

1.3 Structure of the analysis

In order to capture the main microeconomic implications of policy implementation of IPPC the following paragraphs analyse first the microeconomics of pollution abatement, and in particular cross-ambient-pollution-transfer. When the cost model of cutting emission has been outlined we focus on a model of firm's behaviour in three main scenarios:
- no environmental regulation
- regulation with traditional emission limits
- regulation with IPPC.

This part of the analysis should make clearer why IPPC represents a regulatory break point for big plants. Moreover, the analysis should also shed light on the potential links between IPPC and market instruments like TEP.

2 Microeconomics of pollution abatement

2.1 Introduction

The following parts deal with the cost of cutting emissions from a single source using the traditional instruments available in literature. Moreover, we introduce a bit of real world into the models considering "irregular" cost function with breaks due to fixed investments and irrelevant marginal cost.
On this base we discuss the economics of cross-ambient-pollution-transfer and the effect of solid waste disposal cost on the pollution mix.

### 2.2 Three ways of cutting emissions

Emissions abatement can be obtained in three different ways:

\[ x = f(Q) \]  
\[ x^A = f(x^S, x^W) \quad \text{with} \quad x^A + x^S + x^W = k \]  
\[ x = f(T) \]

The first function describes the case of production and emission as inseparable variables. The second function shows that a lower emission level into the receptor A (air) can be obtained transferring pollution to receptor S (soil) or W (water), maintaining constant the total level of emissions \( k \) and consequently the level of output Q.

### 2.3 Derivable total cost function

Assuming that TCR is completely derivable, if there are decreasing returns the marginal contribution of reduction costs in emission reduction is decreasing:

\[ TCR = f(x) \quad f' < 0 \quad f'' > 0 \]

The shape of TCR is then like \( TCR_1 \) in fig 1, where the abatement of pollution is represented on the horizontal axis from right to left.

### 2.4 Total cost function with indivisible fixed investment

Yet, the cost of reducing emissions through end-of-pipe technologies is hardly a subject that can be represented by a continuous function: normally firms buy equipments through which they can get a certain reduction of emissions; if they want to go beyond this level of abatement they must buy supplementary (or more sophisticated) technologies, increasing fixed costs. The practical absence of variable costs suggests that TCR can be represented, with an effort of simplification, as a step function like \( TCR_s \) in fig 1:

\[ TCR_s(x) = (k + 1) \beta \quad \text{with} \quad x_a -(k + 1) \alpha < x < x_a - k \alpha \]

\( \kappa = 0, 1, 2... \)

Where:

\( TCR_d = \) the cost for reducing pollution to zero  
\( \beta = \) the investment in an indivisible unit of abatement technology
\( \alpha = \) maximum amount of pollution abatement that can be obtained by a single investment \( \beta \).

\( k = \) multiplying constant; belongs to natural numbers.

Figure 1 Cost of pollution abatement with derivable TCR and decreasing return and with step function

2.5 Microeconomics of CAPT

For simplicity, let assume that there are three ways to reduce pollutants when there are three receptors and different available techniques:

- transfer to the first alternative receptor
- transfer to the second alternative receptor
- cleaner techniques

As shown in the fig 2, for each receptor there are three curves of marginal cost of reduction. To understand the meaning of the represented curves it should be remembered that reducing emissions along a CT curve means that the firm has changed the production process, or the inputs in order do reduce the overall environmental impact of the production; on the contrary, cutting emission along a CAPT curve (mcr \( ^{AW} \) or mcr \( ^{AS} \)), means that the firm transfers pollutants to water or air. The CT curves plays here a pure evocative role, it must not be directly compared with CPT curves that belongs to a complete different microeconomics.
The mcr\(^{AW}\) and the mcr\(^{AS}\) have a cross point \(x_B\) at which the CAPT from air to water becomes, at the margin, more expensive than the CAPT from air to soil. If we introduce the cost of solid waste disposal in marginal terms (mcd\(^S\)) the mcr\(^S\) shifts upwards according to the fee. The curve now has two components: the technological cost of CAPT from air to soil and the tipping fee to be paid to the landfill.

The following formula is a generalisation for PMC:

\[
PMC^A (x^A) = mcr^{AS} + \delta \quad \text{if} \quad 0 < x^A < x_B^A
\]

\[
mcr^{AW} \quad \text{if} \quad x_B^A < x^A < x_{\pi}^A
\]

Figure 2: the curve of marginal cost of pollution reduction as a path of minimum cost (PMC) along different curves

### 2.6 Marginal cost function and solid waste disposal costs

The relative value of emissions into a particular receptor depends on the adopted technology and the relative level of disposal costs of solid waste into the soil:

\[
x_{\pi}^W / x_{\pi}^S / x_{\pi}^A = f(\text{mcd}^S, T_{\pi})
\]
The minimum cost technology encompasses a given quantity of emissions into different receptors. Moreover, the presence of disposal costs of solid wastes introduces a supplementary variable in the search for maximum profit. Disposal cost for solid waste means that one receptor, the soil, is not free of charge. In this context, the Cross-Ambient-Pollution-Transfer (CAPT) is exclusively due to disposal costs: they can incentive high level of air/water pollution in case of easy CAPT from soil to water or air. In fig 2, if mdc\textsuperscript{S} grows the optimal level of solid waste for the firm (x_{\text{opt}}\textsuperscript{S}) shrinks; a share of solid wastes is transferred in air or water through EOPT. If the CAPT from soil to water shows lower marginal costs, this will be the optimal choice for the firm. The general model of CAPT from soil to other receptors due to different mdc\textsuperscript{S} is as follows:

\[ x_{\text{opt}}=x_{\text{opt}}^{\text{S}} \times K \times x_{\text{opt}}^{\text{S}}/Ce \]  

where:
- \( K \) = disposal cost per unit of solid waste
- \( Ce \) = The marginal cost to reduce waste to zero
- \( x_{\text{opt}}^{\text{S}} \) = The optimal level of production of solid waste in absence of disposal cost

2.7 Environmental quality

All considering, the environmental quality, whatever the regulatory scenario, will result from the sum of emissions in the past, according to profit maximisation rules compatible with regulation, the absorptive capacity of receptors, the dispersion factor and the transformation function of pollutants:

\[ EQ = f(\Sigma i=1..n, \Sigma r=1..m, \Sigma t=\omega...o, \eta_{i}x_{ir}, Hr, D) \]  

where:
- \( \eta_{i} \) = the coefficient that weighs the capacity of a single source of pollution to influence the general EQ (mainly based on distance)
- \( n \) = number of polluting sources
- \( m \) = number of receptors
- \( \omega \) = the more distant year in the past that affects today’s EQ
- \( Hr \) = absorbing capacity of a particular receptor
- \( D \) = dispersion of pollutants

3 How firms react to different regulatory scenarios

3.1 The unregulated firm

In the absence of environmental policy, emission’s level and energy use are supposed to depend on minimum cost (maximum profit) production technique: a
useful way to express this equilibrium is:

$$\text{TCR}(x)=0$$

Where:
TCR = total cost of reduction of emission x

The firm selects the optimal technology and then releases into the environment as much pollution as it needs: the level of pollution released is here is compatible with maximum profit ($x_\pi$). Assuming that the physical/chemical properties of the pollutant does’nt depend on the receptor that hosts it, total emissions form the firm are:

$$x_\pi = x_\pi^W + x_\pi^S + x_\pi^A$$

(10)

3.2 The firm with not-integrated emission limits

3.2.1 Complying with the standard
The traditional standards, in terms of concentrations in media, are expressed as follows:

$$x^a \leq \pi^a$$
$$x^w \leq \pi^w$$

There are no emission limits in the soil (traditional policies doesn’t worry about the amount of dumped waste) and energy use is not considered.

We can consider two scenarios:

a) in the first one the profit maximizing level of emissions is higher than the standard:
$$x_\pi^w > \pi^w$$
$$x_\pi^a > \pi^a$$

Mandatory reduction of pollution in air and water will end in a transfer of pollutants into soil and, probably, a higher level of energy use, given the high energy content of end-of-pipe abatement technologies and waste-hauling;

b) in the second one there is an excess of emissions only for one receptor:
$$x_\pi^w < \pi^w$$
$$x_\pi^a > \pi^a$$

In this case the CAPT will be from air to water or soil, according to the relative level of marginal cost (mcrA and mcdS).
3.2.2 Standards and step function in cutting emission
The case of cost curve of pollution abatement with steps raises a particular problem in setting emission standards. Due to the fact that TCR is mainly determined by fixed investments, marginal cost of pollution abatement are irrelevant.

Figure 3: Standard and step TCR

As shown in fig 3 if authorities set the standard \( X' \), they oblige the firm to make the investment \( 2\beta \); yet, with this investment the firm can reach the standard \( X_2 \) without cost.

3.3 The firm with IPPC

3.3.1 The integrated standard
IPPC means, practically, that the limit of emission per single pollutant is fixed in relation to the plant output or input:

\[ \frac{x}{Q} = L \]

Technical options probably allow to comply with the integrated standard “L” with different set of distribution of x into receptors and different energy-use scenarios. Authorities must decide if it is more desirable, at the margin, to find x in water, air or soil (or a mix).

The answer to the problem requires:
- the knowledge of the pollutant’s cross-ambient physical transfer function (CAPhTF)
hypotheses about the social cost function for each pollutant in each ambient

\[ SC = f(x^W, x^S, x^A) \]  

(11)

In a context of perfect information the optimal policy yields the following result:

\[ mscx^W = mscx^A = mscx^S \]

where \( mscx \) is the marginal social cost of \( x \).

### 3.3.2 EOPT and BAT: a graphical representation

In the fig. 4 the lines represents different Cross-Ambient-Pollution-Transfer-Functions (CAPTF). From right to left, as we will see, the CAPTF entails higher costs because the firm is working with cleaner technologies. The shaded wings of the lines stand for the fact that it is unlikely to find situations in which emission in a receptor is practically nil because it has been totally transferred to the other receptor along a CAPT function of transformation.

Suppose that the optimal level of emission into air and water for the unregulated profit-maximising firm is \( x^W \) and \( x^A \). Now let impose a set of standard like \( x^W \) and \( x^A \): the firm moves along the CAPTF to reach the standards, sustaining a cost that is not showed in the graphic: yet we know that this is a typical EOPT cost.

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**Fig 4: BAT and CAPT**
Suppose now that the standard for air is $x_2^*$: then the firm cannot comply with it along the CAPTF,$^1$ this means that transferring pollutants from one ambient to the other does not permit to comply with two standards simultaneously. In other words the set of standards is too strict for the actual technology. What the company needs to comply with the new regulation is an investment in CT represented by the distance between the higher and the lower CAPTF: this one is the new frontier of pollution transfer at a lower level of overall emissions.

### 3.3.3 From IPPC to tradable permits

Assuming that, in a given situation

$$x_\pi = x_\pi^w + x_\pi^s + x_\pi^A / Q < L$$

and that

$$EQ < EQ$$

where $EQ$ is the environmental quality standard, there is room for more emissions: so the authority can issue new permits. Otherwise the authority doesn't allow any new plant to emit in the area until EQ is lowest than $EQ$. The mechanism, at his core, bring us to the model of tradable permits: a company that is willing to apply for a new plant in the area should be, in theory, willing to pay to an existing plant a given amount of money in order to obtain exactly the reduction of emission that would change the authority denial. With optimal condition in information and transaction costs the company would select the existing polluting plant with the lower cost of pollution abatement, that is exactly what efficiency requires.

### References


