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The Pigouvian Tax Rule in the Presence of an Eco-Industry

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Abstract

Pollution abatement goods and services are now largely being delivered by a specialized "eco-industry". This note reconsiders Pigouvian taxes in this context. We find that the optimal emission tax will depart from the marginal social cost of pollution according to the polluters' and the environment firms' relative market power.

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1. Introduction

In his classical analysis of market failure, Arthur Pigou (1920) showed that the negative externalities caused by pollution would be internalized by the market if polluters paid a tax equal to the marginal social cost of polluting emissions. This proposition, derived under the assumption of perfect competition, was later amended by Buchanan (1969) and Barnett (1980): when the polluting industry is imperfectly competitive, an emission tax should be set *lower* than the marginal social cost of pollution, because it trades off the desire to provide incentives for abatement and the necessity to prevent a greater contraction of output. Several authors (see, for example, Katsoulacos and Xepapadeas 1995, Long and Soubeyran 1999, Morgenstern 1995, and Smith 1992) have now explored, qualified and refined the latter conclusion under more specific industry structures.

All these studies, however, (in fact, all environmental economics so far) postulate that a polluting firm possesses its own internal abatement technology. But nowadays, abatement goods and services are largely procured from specialized environment firms, and this so-called "eco-industry" looks rather concentrated (see Barton 1997, Davies 2002, the European Commission 1999, Karliner 1999, the OECD 1996, and the World Trade Organization 1998). In a recent paper that first acknowledges this situation, David and Sinclair-Desgagné (2005) amended Pigou's basic framework and found that an optimal emission tax should now be set *higher* than the marginal social cost of pollution. Intuitively, imperfect competition between environment firms results in abatement prices larger than the marginal cost of abatement; emission taxes must then be raised in order to make polluters reduce their emissions sufficiently. This note examines whether and to what extent a similar conclusion holds in the Buchanan-Barnett context. The upshot is that the optimal emission tax needs in general to adjust to the polluters' and the abatement suppliers' *relative* market power. It may happen, for instance, that the distortions respectively present on the product and the abatement markets offset each other to the point that the optimal emission tax turns out to be the one prescribed initially by Pigou.

The paper unfolds as follows. Section 2 presents the model. Section 3 derives and discusses our results. Section 4 contains concluding remarks.

2. The model

First consider n identical firms competing *à la* Cournot. Each firm i produces a quantity x_i of a final good at a cost $C(x_i)$, where the latter function is twice differentiable, strictly increasing and convex. Consumers' preferences for this final good are captured by the inverse demand function $p(X)$, $X = \sum_{i=1}^{n} x_i$, $p'(X) < 0$. Each firm also generates polluting emissions according to an emission function $e(x_i, a_i)$, where a_i represents firm i's abatement effort. We assume that $e(x_i, a_i) = w(x_i) - a_i$, $w'(x_i) > 0$ and $w''(x_i) \geq 0$.[1]

Now, let the abatement goods and services be supplied by a Cournot oligopoly comprising m similar environment firms. Firm j's cost of delivering an amount a_j of such goods and services is given by $G(a_j)$, with G' and G'' strictly positive. When the market for abatement is characterized by the inverse demand function $q(A)$, $A = \sum_{j=1}^{m} a_j$, $q'(A) < 0$, each environment firm offers a quantity a_j that maximizes the profit function

$$\Pi_j(a_j) = q(A)a_j - G(a_j) \ .$$

Satisfying simultaneously the (necessary and sufficient) first-order conditions

$$q(A) = G'(a_j) - q'(A)a_j \ , \quad j = 1, ..., m \tag{1}$$

then yields a Cournot-Nash equilibrium for the eco-industry.

From now on, we shall focus on symmetric equilibria, so a representative polluter i's production and abatement are respectively given by $x = \frac{X}{n}$ and $a_i = \frac{A}{n}$, and a representative environment firm j's delivered quantity of abatement is $a_j = \frac{A}{m}$.

3. Optimal emission taxes

Suppose that each unit of pollution bears a positive social cost ν. A benevolent and informed regulator may now want to impose a tax t on polluting emissions. Ignoring redistribution and income transfer issues, this tax would maximize the social welfare objective

$$W(t) = \int_0^{X^t} p(z)dz - nC(x^t) - mG(a_j^t) - nve(x^t, a_i^t),$$

where by symmetry $x^t = \frac{X^t}{n}$, $a_i^t = \frac{A^t}{n}$, and $a_j^t = \frac{A^t}{m}$. After we drop the superscript ^{t} (remembering throughout that abatement and output levels depend on the tax t), the necessary and sufficient first-order condition for an optimal emission tax is given by

$$W'(t) = n[p(X) - C'(x)]\frac{dx}{dt} - nG'\left(\frac{na_i}{m}\right)\frac{da_i}{dt} - n\upsilon\left[w'(x)\frac{dx}{dt} - \frac{da_i}{dt}\right] = 0. \tag{2}$$

[1] Our qualitative results remain valid without assuming an additively separable emission function. This assumption greatly simplifies the upcoming computations, however. It has been used in several previous works (Barnett 1980, Katsoulacos and Xepapadeas 1995, Farzin and Kort 2001, and David and Sinclair-Desgagné 2005). It also fits end-of-pipe abatement activities, such as solid waste management, waste water treatment, air pollution control, contaminated soil and groundwater remediation, which currently draw (by far) the largest share of abatement expenses (European Commission 1999).

A representative polluter will react to this tax by maximizing the profit function

$$\Pi_i(x, a_i) = p(X)x - C(x) - q(A)a_i - te(x, a_i) \ .$$

This is achieved if the following first-order (necessary and sufficient) conditions hold:

$$p(X) - C'(x) = -p'(X)x + tw'(x), \tag{3}$$
$$q(A) = -q'(A)a_i + t. \tag{4}$$

Standard comparative statics on equations (3) and (4) confirms that $\frac{dx}{dt}$ and $\frac{da_i}{dt}$ are respectively negative and positive, meaning that a larger tax on polluting emissions generates less production of the final good and greater abatement efforts.

Substituting (1), (3) and (4) into expression (2) now yields the general formula for the Pigouvian tax rule:

$$t = v + \frac{\frac{X}{n}p'(X)\frac{dx}{dt} + \left(\frac{A}{m} - \frac{A}{n}\right)q'(A)\frac{da_i}{dt}}{w'(x)\frac{dx}{dt} - \frac{da_i}{dt}} \tag{5}$$

Note that the denominator on the right-hand side is negative.

Were the eco-industry perfectly competitive, which amounts here to letting $m \to \infty$, the regulator should set $t = v$ if n also tends to infinity (as Pigou (1920) first proposed) or $t < v$ if n is finite (in agreement with Buchanan (1969) and Barnett (1980), but with an additional downward adjustment due to the term $-\frac{A}{n}q'(A)\frac{da_i}{dt}$ which expresses the polluting firms' oligopsony in the abatement market).

Let now $m < \infty$, so the eco-industry is imperfectly competitive. By (1), the price of abatement in this case is equal to the marginal cost $G'\left(\frac{A}{m}\right)$ *plus* a markup $\frac{A}{m}q'(A)$. This markup further dissuades polluters from investing in abatement. To counter this, the regulator has to play tougher on polluting emissions.[2] Indeed, when n is infinite (so polluters are price-takers), formula (5) coincides with the one obtained by David and Sinclair-Desgagné (2005) and we have that $t > v$. With n also finite, however, the regulator must deal with the exercise of market power by polluting firms in the final good market, which lowers consumer surplus, together with the simultaneous presence of an oligopsony and an oligopoly in the abatement market, which both hinder pollution reduction. After some algebra, the numerator on the right-hand-side of (5) indicates that

$$t \gtreqless v \quad \text{if and only if} \quad \left(\frac{n-m}{n}\right)\left(q(A)\frac{da_i}{dt}\right)L_{ECO} \gtreqless \left(-p(X)\frac{dx}{dt}\right)L_{PROD} \tag{6}$$

where L_{ECO} and L_{PROD} are the Lerner indices associated with the eco-industry and

[2] In practice, environmental policy has to also cope with the possibility of exit from the polluting sector and entry in the eco-industry, and take into account the redistribution of revenues from polluting to environment firms. A careful treatment of these issues is obviously beyond the scope of this note.

the final good market respectively.[3] As the environment firms' market power matters *relatively* more (less), so $\frac{n-m}{n}$ or $\frac{L_{ECO}}{L_{PROD}}$ increases (decreases), the regulator would now impose a higher (lower) tax on emissions. This tax will approximate Pigou (1920)'s recommendation when the upstream and downstream industry structures are such that

$$\frac{L_{PROD}}{L_{ECO}} \approx \frac{m-n}{n} \frac{q(A)}{p(X)} \frac{\frac{da_i}{dt}}{\frac{dx}{dt}} . \tag{7}$$

4. Concluding remarks

This paper showed that taxes targeting polluting emissions must adjust to the relative market power of environment firms (on the abatement market) and polluters (on both the final good and the abatement markets). All things equal, a relatively more concentrated and powerful eco-industry warrants higher emission taxes.

The impact of more complex and realistic industry structures - with endogenous entry and exit, or privately informed and heterogeneous environment firms, for example - on Pigouvian taxes and environmental regulation in general remains to be explored. Pursuing this path, henceforth investigating the vertical relationships and actual division of labor between polluting firms and their abatement suppliers, will certainly shed light on the current black box of abatement costs, for the greater effectiveness of environmental policy.

References

Barnett, A. H. (1980) "The Pigouvian tax rule under monopoly" *American Economic Review* **70**, 1037-1041.

Barton, J. R. (1997) "The North-South dimension of the environment and cleaner technology industries" Discussion Paper no. 9803, Institute for New Technologies, United Nations University, Maastricht, The Netherlands.

Buchanan, J. M. (1969) "External diseconomies, corrective taxes, and market structure" *American Economic Review* **59**, 174-177.

David, M. and B. Sinclair-Desgagné (2005) "Environmental regulation and the eco-industry", *Journal of Regulatory Economics* **28**, 141-155.

[3] Defined as the difference between the firm's price and its marginal cost, divided by the firm's price, the Lerner index is a well-known measure of a firm's market power. Here we have that $L_{ECO} = \frac{q(A)-G(a_j)}{q(A)} = \frac{1}{m|\eta|}$ and $L_{PROD} = \frac{p(X)-C'(x)}{p(X)} = \frac{1}{n|\varepsilon|}$, where ε and η are the price-elasticities of demand for the final good and for the abatement goods and services respectively.

Davies, S. (2002) "Waste management multinationals 2002" Mimeo, Public Services International research Unit (PSIRU), School of Computing and Mathematical Sciences, University of Greenwich.

European Commission (1999) *The EU Ecoindustry's Export Potential: Final Report to DGXI of the European Commission*, European Commission: Brussels.

Farzin, H. and P. Kort (2001) "Pollution abatement investments when environmental regulation is uncertain" *Journal of Public Economic Theory* **2**, 183-212.

Katsoulacos, Y. and A. Xepapadeas (1995) "Environmental policy under oligopoly with endogenous market structure" *Scandinavian Journal of Economics* **97**, 411-420.

Karliner, J. (1994) "The environment industry: Profiting from pollution" *The Ecologist* **24**, 59-63.

Long, N. V. and A. Soubeyran (1999) "Pollution, Pigouvian taxes, and asymmetric international oligopoly" CIRANO, Working Paper.

Morgenstern, R. (1995) "Environmental taxes: dead or alive?" Resources for the Future, Working Paper 96-03.

Organization for Economic Cooperation and Development (1996) *The Global Environmental Goods and Services Industry*, OECD Editions: Paris.

Pigou, A. C. (1920) *The Economics of Welfare*, Macmillan: London.

Smith S. (1992) "Taxation and the environment: a survey" Mimeo, Centre for Social and Economic Research on the Global Environment (CSERGE), University of East Anglia.

World Trade Organization (1998) *Environmental Services*, Chapter IX of the Committee on Trade and Environment's note on Environmental Benefits of Removing Trade Restrictions and Distortions.