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Prices vs quantities with multiple pollutants ☆

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ABSTRACT

We examine the choice of policy instruments (price, quantity or a mix of the two) when two pollutants are regulated and firms' abatement costs are private information. Whether abatement efforts are complements or substitutes is key determining the choice of policies. When pollutants are complements, a mixed policy instrument with a tax on one pollutant and a quota on another is sometimes preferable even if the pollutants are identical in terms of benefits and costs of abatement. Yet, if they are substitutes, the mixed policy is dominated by taxes or quotas.

1. Introduction

Weitzman [33] deals with the choice of policy instruments when firms' costs are private information. When applied to pollution mitigation issues, the choice is between a price such as a tax, and a quantity instrument such as an emission standard. Weitzman [33] shows how this choice is driven by two parameters: the slopes of the marginal benefit of reducing pollution and of the firm's abatement costs. A price-based instrument should be preferred when benefits are relatively flat compared to the costs, while quantity-based instruments are better when benefits are steeper than costs.

The analysis by Weitzman concerns the choice of a policy instrument to regulate a single pollutant. However, in practice, production processes are often accompanied by the emissions of multiple pollutants. Furthermore, abatement can be characterized as a multiple pollutant process whose costs are affected by economies or diseconomies of scope associated with the common use of inputs [12].[1] If the joint abatement creates some synergies (i.e. economies of scope, which can lead to ancillary benefits) pollutants can be considered as complements in the abatement process. Instead, if certain pollutants are reduced at the cost of increasing others (i.e. diseconomies of scope) pollutants can be considered as substitutes [5,3,13].

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[1] The notion of economies of scope is referring to situations where it is less expensive to produce two or more products together rather than separated [23]. In environmental economics, Labonne and Johnstone [10] link the analysis of economies of scope to the choice of technologies to reduce emissions, where firms can decide either to change their production processes (CPP) or adopting end-of-pipe technologies (EOP). If CPP reduces the costs of jointly producing conventional outputs and abatement, it creates economies of scope between production and abatement. Instead, economies of scope within abatement occur if through the use of EOP firms reduce the emissions of several other pollutants at the same time. In this paper, we focus on the latter case.

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The existence of economies/diseconomies of scope within abatement (hereinafter, referred to as complementarity/substitutability in abatement) is well established in the literature and there are examples abound. For instance, catalytic converters for cars simultaneously reduce emissions of nitrogen oxides (NO_x) and volatile organic compounds (VOC) [4], and strategies to reduce nitrogen from sewage plants also reduce phosphorus [7]. In the case of substitutes, scrubbers installed in power plants to neutralize sulfur dioxide (SO_2) use energy and, therefore, lead to more carbon dioxide (CO_2) emissions [19,13]. The increased use of biomass also creates some trade-offs in emissions control. Biomass can be helpful in reducing CO_2 emissions; however, it may also cause increased emissions of nitrogen oxides (NO_x), particulate matter (PM), carbon monoxide (CO) and VOC. In turn, this means a higher risk to human health for the population exposed to these pollutants (see [30,2,27], for empirical evidence).[2]

In this paper, we extend Weitzman's prices vs quantities analysis to multiple pollutants. We compare the performance of different policy mixes when firms can reduce the emissions of two pollutants simultaneously through the use of multi-pollutant abatement technologies. We study the effects of the choice among only emission taxes, only emission norms or non-tradable quotas, and a mixed policy where taxes are used to control the emissions of one pollutant while an emission norm is intended to reduce the emissions of the other. In practice, different combinations of price and quantity policy instruments are used to regulate multi-pollutant firms. For example, in Europe emissions of SO_2 and NO_x are regulated through taxes and in the U.S. emissions of SO_2 are regulated through cap-and-trade while the emissions of several local air pollutants, such as particulate matter or VOC, are mainly controlled through emission standards.

To the best of our knowledge, this is the first study looking at the effects of the choice of policy mixes involving different combinations of price-based and quantity-based regulations in the context of multiple pollutants and asymmetric information. Several papers have analyzed the design of environmental policies with multiple pollutants but under perfect information. In Endres [8], two pollutants interact in the social damage function. However, unlike in the present paper, there is no asymmetric information about abatement costs. Moslener and Requate [19] and Kuosman and Laukkanen [16] deal with multiple pollutant abatement strategies in a dynamic framework. Their focus is on the optimal emission path, and not on the choice of regulation instruments. Climate change mitigation models also consider multi-gas control strategies (see for instance [22,31]) to evaluate emission path scenarios. Montero [21] and Caplan and Emilson [6] analyze the design of environmental regulations with several pollutants. Contrary to our paper, they consider only one instrument, namely marketable emission allowances.

Regarding the interaction of policies in the context of a single pollutant, some authors have analyzed the welfare effects of a hybrid policy encompassing both price and quantity mechanisms in Weitzman's [33] framework (see for instance [29,25]). Notably, Mandell [18] shows that with several firms and one pollutant, a mixed scheme consisting of taxing some firms and regulating others through a cap-and-trade system might be more efficient. Similarly, we provide some rationale for a mixed policy where one pollutant is taxed while the other is limited by an emission standard.

The paper is organized as follows. In Section 2, we compute the abatement levels and welfare under the three policy instruments mentioned above when the two pollutants are symmetric. The regulator knows whether the pollutants are substitutes or complements, but there is asymmetric information regarding the marginal abatement costs. We also discuss the use of hybrid policies in the context of multiple pollutants. We show how a hybrid policy for each pollutant consisting of a tax, a quota and a penalty from exceeding the quota can implement first-best abatement levels. In Section 3, we extend the model in several directions. First, we allow for interaction among pollutants into the damage function. Second, we check the robustness of our results to asymmetric policy stringency between pollutants. Third, we compare tax vs quantity regulations when the substitutability or complementarity parameter is unknown by the regulator. Finally, Section 4 concludes the paper. Proofs are relegated to the appendix.

2. Price vs quantity with complementarity or substitutability

A firm is emitting two pollutants: pollutant 1 and pollutant 2. The pollutants are symmetric in terms of costs for the firm. The total cost of reducing emissions by q_i units for $i=1, 2$ for the firm is

$$C(q_1,q_2,\theta)=\frac{mq_1^2}{2}+\frac{mq_2^2}{2}+\omega q_1 q_2+\theta[q_1+q_2].$$

Consistent with Panzar and Willing [23], economies (diseconomies) of scope exist when for all abatements $q_1>0$ and $q_2>0$, the cost of joint abatement is less (more) than the cost of abating each pollutant separately. Formally, there are economies of scope if $C(q_1,q_2,\theta)<C(q_1,0,\theta)+C(0,q_2,\theta)$. There are diseconomies of scope if the reverse holds. We refer to

[2] Other examples can be found in agriculture. Farmers can decrease their use of chemical fertilizers (and thus NO_2 emissions) by substituting with natural fertilizers from cattle breeding but at a cost of producing more methane. Pesticide can be complements or substitutes to fertilizers depending on the targeted pests. Some authors have estimated the elasticities of substitution between different pollutants. For example, Leightner [11] computes the elasticity of substitution between NO_x an SO_2 in electricity generation in Thailand. He finds that by allowing SO_2 concentrations to increase by 1%, NO_x concentrations can on average be reduced by 4.03% while holding electricity and all other inputs constant. Holland [13] estimates whether CO_2, SO_2 and NO_x emissions are gross or net substitutes or complements by decomposing into output and substitution effects in power plants in California, United States. His results are consistent with gross complementaries, with most of the emissions'reduction being achieved though output effects at older plants. Kumar and Magani [15] compute the elasticities of substitution between water pollutants in India. They find that organic pollutants such as biological and chemical oxygen demand (BOD and COD, respectively) are complements to one another; instead, the relationship between BOD and suspended solids is one of substitutability.