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Emissions standards and ambient environmental quality standards with stochastic environmental services

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ABSTRACT

Many important environmental policies involve some combination of emission controls and ambient environmental quality standards, for instance SO_2 emissions are capped under Title IV of the U.S. Clean Air Act Amendments while ambient SO_2 concentrations are limited under National Ambient Air Quality Standards (NAAQS). This paper examines the relative performance of emissions standards and ambient standards when the natural environment provides stochastic environmental services for assimilating pollution. For receiving media characterized by greater dispersion in the distribution of environmental services, the optimal emissions policy becomes more stringent, whereas the optimal ambient policy generally becomes more lax. In terms of economic performance, emissions policies are superior to ambient policies for relatively non-toxic pollutants, whereas ambient standards welfare dominate emissions standards for sufficiently toxic pollutants. In the case of combined policies that jointly implement emissions standards and ambient standards, we show that the optimal level of each standard relaxes relative to its counterpart in a unilateral policy, allowing for greater emissions levels and higher pollution concentrations in the environmental medium.

1. Introduction

Most industrial countries adopt environmental policies that involve some combination of emissions controls and ambient environmental quality standards. Ambient standards, which set limits on allowable pollution concentrations in receiving environments, have been implemented since the U.S. Rivers and Harbors Act of 1899 and they currently serve as the backbone of U.S. environmental policy in the National Ambient Air Quality Standards (NAAQS) of the Clean Air Act and in the Water Quality Standards (WQS) of the Clean Water Act.[1] Yet, despite the long-standing use of ambient standards to control environmental externalities, the trend in environmental policy over the last several decades has been towards the use of emissions controls, typically in the form of "cap and trade" programs.

The recent gravitation of environmental policy towards emissions instruments in many cases has led to overlapping policies that combine ambient standards with emissions standards. For example, the U.S. cap and trade programs for sulfur

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[1] NAAQS set allowable pollution concentrations for six so-called "criteria pollutants" – Carbon Monoxide (CO), Nitrogen oxides (NO_x), Ozone (O_3), Lead (Pb), Sulfur Dioxide (SO_2), and Particulate matter (PM_{10} and $PM_{2.5}$) – and specify both an acceptable annual mean concentration and a maximum concentration in a given interval of time, generally the second highest 24-h period each year. For more details on the requirements of the U.S. Clean Air Act, see Lave and Omenn [13] and Liroff [14].

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dioxide (SO_2) and for nitrogen oxides (NO_x) currently operate in conjunction with ambient standards on SO_2 and NO_x concentrations under NAAQS.[2] Given the long-standing prevalence of ambient standards in U.S. environmental policy, it is surprising to note that the economic performance of ambient environmental quality standards and emissions standards have not been examined in settings where the natural environment has a stochastic ability to assimilate pollution.

In this paper we consider the relative performance of optimal emissions standards and optimal ambient environmental quality standards when emissions and environmental services jointly produce ambient environmental quality. Specifically, we model ambient pollution concentrations as the product of emissions and a stochastic environmental input, for instance when pollution is released into receiving water with variable streamflow. We examine the relative performance of emissions standards and ambient standards under circumstances in which environmental policy cannot be fully customized in a system of state-contingent pollution controls.

Our framework has several interpretations. One interpretation is that polluting firms have superior information on the extent of environmental services available to assimilate their pollution while environmental services are stochastic from the perspective of the regulator. A second interpretation is that the regulator has full information regarding environmental services, but the extent of environmental services available at a given time varies temporally and spatially in the receiving media at a rate that makes fully adoptive policies infeasible. Our policy comparison thus encompasses ambient standards of the form underlying NAAQS and WQS that stipulate uniform limits on pollution concentrations across a diverse set of regional airsheds and water bodies in the U.S. as well as emissions standards of the form underlying U.S. cap-and-trade programs for SO_2 and NO_x of the Clean Air Act and pollution discharge permits of the Clean Water Act.

We organize the paper by first examining the properties of the optimal ambient standard and optimal emissions standard for each policy levied in isolation. When damage functions are convex in pollution concentrations, we demonstrate that the optimal emissions standard becomes more stringent (i.e., mandates lower emissions) when the receiving media is characterized by greater dispersion in environmental services; however, the optimal ambient standard can become either more stringent (require lower pollution concentrations) or more lax. We provide sufficient conditions for the ambient standard to relax in response to greater dispersion in environmental services. This allows us to characterize how the optimal uniform ambient standard is amended when the level of environmental services is drawn from a distribution with greater dispersion of receiving conditions, for instance in air basins such as Los Angeles that are prone to temperature inversion.

We also consider the relative economic performance of emissions standards and ambient standards as environmental policy instruments. We find emissions standards to be superior to ambient standards for relatively non-toxic pollutants, while ambient policies welfare dominate emissions policies for sufficiently harmful pollutants. The reason is that emissions policy equalizes marginal abatement cost across polluters, which economizes on compliance costs. Nevertheless, uniform emissions policies that align marginal abatement cost among polluters can lead to "hot spots" with highly damaging pollution concentrations in receiving media that provide little in the way of environmental services. Indeed, it is precisely this shortcoming of emissions policy – the inability to predict where traded emissions ultimately are released – that prompted the U.S. EPA to limit SO_2 and NO_x emissions trading across state lines under the Cross-State Air Pollution Rule (CSAPR) of 2011.

We examine the design of optimal "over-lapping" policies that incorporate emissions standards in markets with pre-existing ambient standards. We show that policies that jointly implement ambient standards and emissions standards involve less stringent standards relative to a unilateral environmental policy of either type. Thus, when an emissions standard is introduced in a market with a pre-existing ambient standard, the optimal emissions standard allows for greater pollution levels than would be desirable under a unilateral emissions policy and the optimal ambient standard relaxes to allow for higher pollution concentrations in the receiving medium than would be optimal absent for an over-lapping emissions standard.

Our analysis of emissions standards and ambient standards with stochastic environmental services is related to previous work following Weitzman [19] that considers taxes and standards on emissions when firms have stochastic benefits (or costs). Beavis and Walker [2], Beavis and Dobbs [1], and Innes [10], which are the papers closest to ours, consider circumstances in which firms respond to environmental policy by making production or abatement decisions that result in stochastic pollution levels. Our paper departs from this literature by modeling ambient environmental conditions as the product of firms' decisions on emissions levels and nature's draw of environmental services. A distinguishing feature of our framework is that firms can observe the level of environmental services being provided and adjust their pollution loads in response to prevailing receiving conditions, for instance by exploiting periods of high streamflow to release effluent into receiving water. The ability of firms to adjust to spatial and temporal variation in environmental services under ambient standards is a neglected element of pollution control policy that is particularly germane in light of recent empirical evidence by Henderson [8] that U.S. firms vary their emissions levels with environmental conditions under NAAQS.

Our analysis is also related to the literature on relative standards. Hochman and Zilberman [9], Harford and Ogura [6] and Helfand [7] examine standards that limit emissions per unit of output in competitive markets, and compare the

[2] The NAAQS primary standard for SO_2 establishes a 1-h standard of 75 ppb on ambient SO_2 concentrations. The cap and trade system for SO_2 currently limits annual emissions among electric utilities to 8.95 million tons under Title IV of the Clean Air Act Amendments of 1990.