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Experimental evidence on dynamic pollution tax policies☆

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ABSTRACT

This paper uses laboratory experiments to provide primary empirical evidence on dynamic pollution tax policies. In particular, we investigate a setting where a regulator with incomplete information uses a pollution tax mechanism with a simple, endogenous tax rate adjustment rule to cost-effectively meet a pollution standard. This mechanism provides the opportunity for firms to strategically abate in order to reduce future tax rates. The experiments vary important policy design features such as the type of tax (ambient or emissions), the initial tax rate, and the tax rate adjustment speed. We find that in equilibrium the pollution standard is met on average for each of these settings. The observed long-run tax rates vary considerably across policy designs, which can be explained with a theory that allows for a mix of strategic and myopic firms, along with the recognition that the incentives generated by the policy design can influence whether an agent plays myopically or strategically.

1. Introduction

Though the Pigouvian tax solution to pollution externalities has theoretical appeal and has been popularly embraced in the form of the "polluter pays" principle, its practical implementation is encumbered by a number of factors. Prominent amongst these is uncertainty surrounding underlying pollution damage and abatement cost functions. In their influential book, Baumol and Oates (1988) argue that difficulties in accurately measuring damage functions preclude the implementation of optimal, efficiency-maximizing taxes, shifting attention instead to cost-effective solutions to reach an exogenously determined pollution standard. Even then, asymmetric information between regulators and firms regarding abatement technologies and cost functions impedes the identification of cost-effective tax rates. Since at least Baumol and Oates (1971), and

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Baumol (1972), a potential way to circumvent the problem of incomplete abatement cost information is to make iterative adjustments to pollution tax rates, using signals relayed through past behavior.

> "Though we are unable to determine in advance precisely a set of tax values that will achieve the desired output standards, the output level achieved by a given tax arrangement is readily observed and, at least in principle, it is possible to learn by trial and error, continuing in the direction of change of any tax modifications that turn out to bring outputs closer to their target levels" (Baumol, 1972, p. 319).

However, in introducing this approach, Baumol and Oates expressed some caution about the properties of such an iterative process, noting: "It is not clear, however, even in theory whether this sequence will in fact converge toward the optimal tax and resource allocation patterns" (1971, p. 44).

Several papers (e.g. Conrad, 1991; Karp and Livernois, 1994; Moledina et al., 2004; Querou, 2008) have explored the theoretical properties of dynamic pollution tax instruments – i.e. mechanisms with an endogenously adjusting tax rate – in models of incomplete information, demonstrating theoretically that potential strategic responses by polluters can affect firm-level emissions and equilibrium tax rates. In particular, excess abatement provides a signal that the current tax rate is higher than necessary to achieve the pollution objective and, accordingly, that the future tax rate should be lowered. As a result, the dynamic tax provides an incentive for firms to over-abate in the short run in order to maximize the net present value of profits. These studies have assumed symmetric play of regulated firms and have typically compared convergence criteria of "myopic" players that act as if in a one-shot, static decision framework and "strategic" players that account for the dynamic impact of present emission decisions on future tax rates. The practical importance of strategic incentives in the context of environmental policy remains a critical empirical question.

This study complements the existing theoretical literature on dynamic taxes by providing primary empirical evidence on dynamic tax policies through laboratory experiments. Tax policies, environmental or otherwise, are inherently dynamic and consideration of many important issues such as revenue generation, market impacts, administrative costs, and public opinion of course are at play when imposing and changing tax rates. There are some policies, however, such as the Everglades Forever Act, where tax rate changes are explicitly tied to whether an environmental outcome is achieved (Segerson, 1997). As myriad extant environmental tax policies pass beyond their infancy, and continue to gain political acceptance, it is natural to believe that environmental tax rates will adjust (based on stated rules or otherwise) at least in part due to environmental quality considerations.

Our experimental design employs the simple (linear) and transparent tax rate adjustment rule analyzed theoretically in Karp and Livernois (1994) and Karp (2005), and focuses on potentially important features of policy design, including: the type of tax (individual emissions-based taxes or group, ambient-based taxes); the initial tax rate (above or below the optimal static tax); and the speed at which the tax rate adjusts across decision periods (fast or slow). Our efforts are very much in the spirit of arguments made by Levitt and List on the virtues of laboratory experiments, specifically: "We also view laboratory experimentation as a useful first step in the area of policymaking" in that such efforts provide "qualitative evidence" on policy mechanisms (Levitt and List, 2006, pp. 40–41).

Although both emissions and ambient taxes are applicable in regulating point sources, the ambient tax is better suited for a non-point source pollution setting, such as for the regulation of agricultural runoff into surface waters, where the regulator lacks the ability to effectively monitor emissions on a firm-by-firm basis (see Segerson, 1988). A substantial body of experimental economics research on ambient-based pollution policies for addressing non-point source pollution has emerged over the years (e.g. Alpízar et al., 2004; Cochard et al., 2005; Poe et al., 2004; Spraggon, 2002, 2004; Suter et al., 2008, 2010; Vossler et al., 2006), but there is a paucity of experimental research, beyond Plott's (1983) seminal study, on tax-based approaches to regulate point source pollution. Importantly, the experimental research to date on both point and non-point source tax policies has evaluated static regulatory mechanisms under the assumption that the regulator has complete information from which to parameterize the optimal policy instrument. By relaxing this assumption, this paper takes an important next step in the experimental pollution tax literature.

As there is no existing empirical evidence to suggest whether all or even some players in a dynamic tax setting will behave strategically, to guide the experimental design and analysis we consider an extension of Karp and Livernois (1994) and Karp (2005) that allows for the regulated group to include both myopic and strategic players. We find experimentally that aggregate emissions are statistically equal to the pollution standard in later decision periods for all the policy settings we consider. This is consistent with the theoretical steady-state equilibrium, which is the same regardless of the number of strategic players. The observed tax rates, however, are found to deviate from the optimal static tax rate. The effects of policy design and treatment conditions on observed tax rates are best organized with a theory that assumes a mix of myopic and strategic players, and further assumes that the decision to play myopically or strategically critically depends upon the corresponding incentives generated by the policy design.

2. Dynamic tax mechanisms

In this section we outline the theoretical properties of the linear dynamic emissions tax mechanism of Karp and Livernois (1994), and the linear dynamic ambient tax of Karp (2005), which form the basis of our experimental design. In the discussion that follows, our intent is to highlight the main findings from the above papers as they pertain to the polar cases where all firms are strategic or all firms are myopic, and provide insight on the intermediary cases.