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Optimal trading ratios for pollution permit markets☆

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ABSTRACT

We demonstrate a novel method for improving the efficiency of pollution permit markets by optimizing the exchange of emissions through trade. Under full-information, it is optimal for emissions to exchange according to the ratio of marginal damages. Under asymmetric information, we derive necessary conditions for the marginal damage trading ratios to be optimal, illustrate that the marginal damage trading ratios are generally not optimal, and show how to improve efficiency using optimal trading ratios. We calculate the optimal trading ratios for a global carbon market. The gains from using optimal trading ratios rather than marginal damage trading ratios range from substantial to trivial, which suggests the need for careful consideration of asymmetric information when designing permit markets.

1. Introduction

Incentive-based environmental regulations, such as permit markets or emissions taxes, have typically been designed to minimize the costs of achieving emissions targets.[2] Focusing on reducing abatement costs simplifies program implementation by eliminating the need to quantify damages from emissions of pollution. However, advances in air and water quality modeling now make it feasible to estimate damages precisely and thereby to incorporate them into program design. This suggests that regulators should turn from the narrow criterion of minimizing abatement costs to the more general criterion of efficiency that accounts for both abatement costs and damages (Muller and Mendelsohn, 2009).

We analyze a novel method for improving the efficiency of pollution permit markets by optimizing the way in which emissions are exchanged through trade. In our model there is asymmetric information between the regulator and the regulated sources of pollution (à la Weitzman, 1974), and the sources can be differentiated by the number of permits they are required to hold for each unit of emissions (à la Montgomery, 1972). When sources trade permits, these differentiated requirements govern the exchange of emissions, and hence are typically called trading ratios. Several recent studies have shown that selecting trading ratios equal to the ratio of expected marginal damages can substantially increase efficiency relative to the one-for-one trading found in many permit markets (Williams, 2002; Farrow et al., 2005; Muller and Mendelsohn, 2009; Henry et al., 2011; Fowlie and Muller, 2013). Taking this as a point of departure, we ask if further efficiency improvements are possible. The rather surprising answer is yes. We derive necessary conditions for the marginal damage trading ratios to be optimal and characterize the optimal trading ratios. These results show that the optimal trading ratios generally depart from the marginal damage trading ratios.

The reason that marginal damage trading ratios may not be optimal is the presence of asymmetric information about the costs of reducing pollution between the sources and the regulator that designs the market. Indeed, in a first-best environment with full information, the marginal damage trading ratios are optimal. However, permit markets are generally employed to allow firms to respond flexibly to private information about their abatement costs. This information is typically

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2 In practice, these regulations have proven quite successful (Carlson et al., 2000; Ellerman et al., 2000; Keohane, 2006; Fowlie et al., 2012).

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not available to the regulator when the regulator designs the program (Weitzman, 1974). In such a second-best environment, the regulator must account for the damages from pollution as well as the uncertainty about abatement costs when selecting the optimal trading ratios.

To understand how this leads to a divergence between the optimal trading ratios and the marginal damage trading ratios, and to see the difference between our approach and other methods of accounting for asymmetric information, it is helpful to consider uniformly mixed pollution such as greenhouse gas (GHG) emissions. Here marginal damages are equal across sources, and the marginal damage trading ratios actually imply one-for-one trading. But one-for-one trading is generally not the most efficient structure. Due to the asymmetric information, the regulator cannot set the aggregate permit endowment (i.e. the "cap") at the ex post optimal level. The cap is either too tight, in the case abatement costs are higher than expected, or is too loose, in the case abatement costs are lower than expected.

There are several ways to approach this problem. One might seek an answer in the mechanism design literature.[3] Here the sources would provide a report about their private information to the regulator in advance of the market. The regulator would design the market based on the information provided by the sources in such a way that the sources have the incentive to truthfully reveal their costs. In practice however, mechanisms of this type have not been used for permit market design, perhaps because they greatly increase the complexity of the market. Another approach is to allow the cap to change in response to market conditions.[4] For example, implementing a price ceiling allows the cap to expand when abatement costs are high, which improves efficiency. Several proposed permit markets have included provisions for a price ceiling. But the efficiency gains of a price ceiling may be mitigated by speculative attacks on it (Stocking, 2012; Hasegawa and Salant, 2014), and adding a price ceiling to a permit market once again increases its complexity. These issues with the standard approaches suggest scope for an alternative way to improve efficiency that retains the simplicity of a basic permit market, at least from the point of view of the sources.

Our approach is to improve efficiency by adjusting the trading ratios away from marginal damages. This creates flexibility in total emissions even though the number of permits is fixed at the cap. For example, if a firm with a relatively low trading ratio sells a permit to a firm with a relatively high trading ratio, then the total emissions of pollution decrease. By selecting the trading ratios optimally, the regulator can, in effect, allow increased emissions when the costs are high and require decreased emissions when costs are low. Although this argument is most intuitive for uniformly mixed pollution, the general point applies to non-uniformly mixed pollution as well. In either case, efficiency can be improved by using optimal trading ratios rather than marginal damage trading ratios.

The importance of our analysis of optimal trading ratios is buttressed by three observations. First, regulators are incorporating trading ratios into a variety of existing and proposed permit markets. Despite this growing interest, optimal implementation of trading ratios has not been studied. Second, regulators are grappling with how to regulate non-uniformly mixed pollution. Permit markets with trading ratios are well suited for this task. Third, proposed markets to limit GHG emissions would swamp existing permit markets in size and scope. The massive scale of such programs implies that efficiency gains from using optimal trading ratios could be quite large in absolute terms, even if they are small in relative terms.

Given these observations, it is not sufficient to just delineate the optimal trading ratios, we must also investigate the practical importance of using optimal trading ratios rather than marginal damage trading ratios. We accomplish this through the numerical analysis of a multi-country carbon emission market. We show that the optimal trading ratios lead to efficiency improvements relative to marginal damage trading ratios. The magnitude of these improvements varies from significant to trivial, depending in particular on the regulators' uncertainty about abatement costs. This suggests that regulators should give careful consideration to the structure of asymmetric information when designing future permit markets.

Our analysis combines two prominent strands of the literature on incentive based regulations. The first is based on Montgomery (1972), who formally introduced the idea of trading ratios in permit markets. Montgomery recognized that, if damage from pollution differs across sources, then emissions licenses should not simply trade one-for-one. His proposed trading rules are consistent with marginal damage trading ratios.[5] The second is based on Weitzman (1974), who introduced the idea of informational asymmetries in permit markets. Because the parameters of permit markets must be set potentially years in advance, the regulator lacks information which will be available to market participants when they make abatement decisions. This asymmetric information has important implications for the choice of policy instruments and the resulting literature on "prices vs. quantities" is vast.[6] We are interested in a different question: What happens to Montgomery's trading ratios when we apply Weitzman's fundamental insight about asymmetric information? There has not been a systematic study of this issue.[7]

The authors who come closest to disentangling the relationship between trading ratios and asymmetric information are Fowlie and Muller (2013). In analyzing a model with quadratic abatement costs and linear damages, they observe that, under asymmetric information, the marginal damage trading ratios may not perform as well as simple one-for-one trading. This suggests, of course, that there may be a completely different set of trading ratios that dominate either benchmark. But they do not pursue this line of inquiry. To replicate their observation, we construct a simple numerical example in which one-for-one trading does indeed dominate the marginal damage trading ratios. We go on to calculate the optimal trading ratios and show that they perform better than either the marginal damage trading ratios or one-for-one trading.

Section 2 presents the model and derives the main results. We describe necessary conditions for the marginal damage trading ratios to be optimal and characterize the optimal trading ratios. We additionally analyze source-specific taxes and show that they generally depart from expected marginal damages. Section 3 analyzes a special case of the model in which the abatement costs and damages have the familiar linear-quadratic form. This additional structure enables us to determine necessary and sufficient conditions for the optimality of marginal damage trading ratios. In Section 4 we discuss information issues associated with implementing both marginal damage and optimal trading ratios. In Section 5, we use a simple two-source example of a linear-quadratic model to provide a numerical illustration of the main results. Section 6 presents a preliminary calculation of the gains from optimal trading

[3] Prominent works on regulation and mechanism design include an early example by Baron and Myerson (1982) and a survey by Laffont and Tirole (1993). For environmental issues specifically, see Kwerel (1977) and a survey by Lewis (1996).

[4] Roberts and Spence (1976) first proposed this approach. See also Unold and Requate (2001), Fell and Morgenstern (2010), Hasegawa and Salant (2014), Grüll and Taschini (2011), and Stocking (2012).

[5] Montgomery proposed trading at the ratio of the transfer coefficients. The ratio of the transfer coefficients is exactly the ratio of marginal damages *holding ambient concentrations at the other sites constant*. More recent work estimates the marginal damage trading ratios for several prominent non-uniformly mixed pollution problems (Muller and Mendelsohn, 2009; Henry et al., 2011; Fowlie and Muller, 2013).

[6] For example, Weitzman's framework has been extended to include enforcement costs (Montero, 2002), stock pollutants (Newell and Pizer, 2003), strategic behavior (Moledina et al., 2003), and intertemporal trading (Fell et al., 2012).

[7] A few authors have chipped away at the edges. Yates and Cronshaw (2001) and Feng and Zhao (2006) determine the optimal intertemporal trading ratio in models with a specific damage function. Rabotyagov and Feng (2010) observe that the trading ratios may not be equal to the transfer coefficients, but their focus is on cost-effectiveness, rather than efficiency.