Journal of Environmental Economics and Management 87 (2018) 52–71

Contents lists available at ScienceDirect

Journal of Environmental Economics and Management

journal homepage: www.elsevier.com/locate/jeem

# Multiple pollutants, co-benefits, and suboptimal environmental policies ☆

Don Fullerton [a,*], Daniel H. Karney [b]

[a] University of Illinois at Urbana-Champaign and NBER, United States
[b] Ohio University, United States

ARTICLE INFO

*Article history:*
Received 15 March 2016
Available online 24 August 2017

*Jel codes:*
H23
Q3
Q4
Q5

*Keywords:*
Climate policy
Carbon tax
Pollution permits
Co-benefits
Second best
General equilibrium
Welfare effects
Leakage
Sulfur dioxide
Greenhouse gas emissions

ABSTRACT

In our analytical general equilibrium model, polluting inputs can be substitutes or complements. We study a tax increase on one pollutant where the other faces a tax or permit policy. Our solutions highlight key parameters and welfare effects with gains from abatement plus positive or negative co-benefits from other pollutants in the covered and uncovered sectors. We demonstrate several ways taxes and permits differ. First, the change in taxed pollutant depends on whether the other pollutant faces a tax or permit policy. Also, only with a tax on the other pollutant can a co-benefit arise. The sign of co-benefits depends on the sign of cross-price elasticities and on whether the other pollutant's price is above or below marginal damages. Finally, the other pollutant's tax or permit policy also affects emissions in the uncovered sector (leakage). In a numerical illustration of carbon tax in U.S. electricity, we calculate emissions of $CO_2$ and $SO_2$ in both sectors. For plausible parameters, co-benefits are larger than direct



## Introduction

In a multiple pollutant setting, the first-best can be achieved when each pollutant faces a tax or permit price that reflects its marginal environmental damage (Hanley et al., 2007, pp. 138–149). Not all pollutants are regulated, however, and even regulated ones likely face suboptimal policy. Thus, multiple pollutants create complications for regulators: tightening rules on one pollutant can affect emissions of other pollutants. Policymakers who adopt a new carbon policy may not be able to adjust each regulation on other types of pollution, especially where different laws and jurisdictions govern different pollutants. In fact, studies of a particular regulation may include "ancillary" co-benefits from reducing other pollutants (Burtraw et al., 2003, Groosman et al., 2011, Kolstad et al., 2014).

☆ We are grateful for suggestions from Stefan Ambec, Kathy Baylis, George Deltas, Firouz Gahvari, Garth Heutel, Stephen Holland, Jonathan Hughes, Ben Marx, Nick Muller, Till Requate, Ian Sue Wing, and anonymous referees. All mistakes are our own. Our email addresses are dfullert@illinios.edu and karney@ohio.edu. Mail can be sent to Fullerton at the Finance Department, University of Illinois at Urbana-Champaign, Champaign IL 61820 (phone is 512–750-6012).

* Corresponding author.
*E-mail addresses:* dfullert@illinios.edu (D. Fullerton), karney@ohio.edu (D.H. Karney).

http://dx.doi.org/10.1016/j.jeem.2017.08.003
0095-0696/© 2017 Published by Elsevier Inc.

To consider the general problem of multiple pollutants, our simple analytical general equilibrium model has two sectors with competitive markets and constant returns to scale production functions. Our standard assumptions include full information, perfect factor mobility, and certainty, but a less standard assumption is that each sector has three inputs: a clean input and two kinds of pollution. With three inputs, any pair can be complements or substitutes. We refer to the clean input as labor, but it could represent labor, human capital, physical capital, or a composite of all clean inputs. For concreteness, our primary numerical example has one sector for electricity generation and another sector for the rest of the economy (including transportation), where both sectors use inputs of labor, sulfur dioxide ($SO_2$), and carbon dioxide ($CO_2$). Both pollutants in both sectors may face existing suboptimal policies, and then we consider a small increase in the tax on only one pollutant in one "covered" sector (e.g., carbon tax only in electricity generation). All equations are differentiated to linearize the model and to solve for the effects of that small policy change on all prices, quantities, and economic welfare.

The point of the general model is that raising a tax on one pollutant might increase or decrease the other pollutant. Thus, the model can encompass the example of Sigman (1996) who studies chlorinated solvents used for metal cleaning and degreasing; she finds that raised disposal costs for liquid chemical wastes leads to more air emissions. The empirical literature has many such examples.[1] Regarding our specific numerical example for electricity generation, Färe et al. (2012) find that nitrogen oxides ($NO_X$) and sulfur dioxide ($SO_2$) are substitutes in production, but Agee et al. (2014) argue that $CO_2$ and $SO_2$ could be substitutes *or* complements.[2] If they were substitutes, then a tax on $CO_2$ could lead to more $SO_2$, but the U.S. EPA assumes that a carbon tax reduces use of coal and therefore both $CO_2$ and $SO_2$ (i.e. complements). In this case, a carbon tax can have large positive co-benefits if it reduces damages from $SO_2$.

Another complication, however, is that $SO_2$ from power plants has been limited in the U.S. by a fixed number of permits under the Acid Rain Program (as studied by e.g., Schmalensee et al., 1998, Burtraw et al., 1998, Carlson et al. 2000). In this case, if a carbon tax changes demand for $SO_2$, then permit prices may rise or fall depending on the degree of carbon and sulfur complementarity in production. But, if permits fix the quantity of $SO_2$, then the carbon tax has *no* co-benefit from reducing sulfur emissions.

For these reasons, our general model allows each pollutant to face a pre-existing tax or permit price. Thus, we analyze four combinations. The case where both face a tax provides important baseline results showing the importance of cross-price substitution elasticities. We solve explicitly for the tax-tax and tax-permit scenarios, but the model is symmetric, so the permit-tax and permit-permit scenarios are analogous. Interestingly, we only need to consider the two pollutant policies in a "covered" sector (e.g., electricity generation), even though the other sector may also emit both types of pollution.

While some features of our model have appeared before, we obtain new results by combining all four of the following. First, we model analytically the general case where two pollutants can be complements or substitutes in production.[3]

Second, all pollutants need not be controlled by the same type of policy. While one pollutant might be subject to a tax, another is restricted by permits. Therefore, we use a framework that can analyze all combinations of tax or permit policies and allow for a relatively easy comparison of policy scenarios available to regulators.[4]

Third, these policies are likely not optimal; the price per unit of pollution does not equal marginal environmental damage. A pollutant's policy may not be optimal for at least three reasons: technical limitations and information constraints may preclude correct estimation of social costs and benefits; political concerns may prevent adoption of a first-best policy; and, a pollution tax would reflect conditions at the time of enactment rather than current conditions. Furthermore, multiple pollutants – even from a single source – may not have a single regulator using a comprehensive approach. We address situations where one regulator chooses a policy given regulations on other pollutants.[5]

Fourth, a pollution tax or permit system is unlikely to cover all sectors. The newly proposed Clean Power Plan applies only to the electricity generating sector, for example, just as did the Acid Rain Program of $SO_2$ permits. A carbon tax might be able to cover more than just power plants, but it cannot cover all carbon emissions from small industry and residential sources (Metcalf and Weisbach, 2009). If it does not cover the entire economy, then a rise in the carbon price in the covered sector may have multiple second-best effects, as carbon emissions shift to uncovered sectors (i.e. carbon leakage).[6]

---

[1] Greenstone (2003) finds no evidence for iron and steel that the Clean Air Act increased water or ground pollution, but Gibson (2015) looks at a wider set of industries and finds that it increased water pollution. Gamper-Rabindran (2006) finds that off-site recycling is a substitute for chemical waste disposal. Ren et al. (2011) find that reducing $CO_2$ by the use of biofuel can increase nitrogen runoff from farms.

[2] In response to $SO_2$ controls, the switch to low-sulfur coal with lower heat rate could increase $CO_2$ per kilowatt hour. Also, desulfurization equipment uses electric power that requires burning more coal and may generate added $CO_2$ emissions from the chemical reactions that capture $SO_2$. If the response is to shut down dirty plants, then effects on $CO_2$ depend on whether new plants use coal or natural gas. They find (p.81) that the "marginal effect on $CO_2$ emissions from reducing $SO_2$ is negative" (i.e. complements).

[3] For examples of other models with multiple pollutants that could be complements or substitutes in production, see Moslener and Requate (2007), Holland (2012b), Ren et al. (2011), and Agee et al. (2014).

[4] Ambec and Coria (2013) also analyze a mix of taxes and permits when pollutants can be substitutes or complements, using a "prices v. quantities" approach of Weitzman (1974). They rank welfare outcomes of policy mixes. Our paper differs first by using a general equilibrium approach and second by assuming perfect certainty. Third, because they solve for optimal combinations of policy, they do not consider co-benefits. We consider *sub*-optimal policy, so a change in carbon tax may affect other pollutants that are not priced optimally. Then the change in that other pollutant can provide positive or negative co-benefits.

[5] Moslener and Requate (2007) derive optimal abatement strategies in a dynamic multi-pollutant model. We limit our analysis to welfare effects of small changes from a suboptimal equilibrium, because many studies already consider first-best and second-best optimal policy with other distortions.

[6] Baylis et al. (2014) analyze and discuss the carbon leakage issue in greater detail. In addition, Holland (2012a) and Karp (2013) provide recent, analytical models of carbon leakage.