Resource and Energy Economics 33 (2011) 496–514

Contents lists available at ScienceDirect

Resource and Energy Economics

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

Optimal taxation of externalities interacting through markets: A theoretical general equilibrium analysis☆

Xiaolin Ren [a,*], Don Fullerton [b], John B. Braden [c]

[a] Climate & Global Dynamics Division, National Center for Atmospheric Research 3090 Center Green Drive, Boulder, CO 80301, USA
[b] Department of Finance & Institute for Government & Public Affairs, University of Illinois, 515 E. Gregory Drive, Box 30, Champaign, IL 61820, USA
[c] Department of Agricultural & Consumer Economics, University of Illinois, 1301W. Gregory Drive, Rm 304, Urbana, IL 61801, USA

ARTICLE INFO

Article history:
Received 24 February 2010
Received in revised form 14 October 2010
Accepted 21 October 2010
Available online 30 October 2010

JEL classification:
D50
H23
Q58

Keywords:
Second-best tax
Multiple externalities
Biofuel
GHG emissions
Nitrogen leaching

ABSTRACT

This study develops a theoretical general equilibrium model to examine optimal externality tax policy in the presence of externalities linked to one another through markets rather than technical production relationships. Analytical results reveal that the second-best externality tax rate may be greater or less than the first-best rate, depending largely on the elasticity of substitution between the two externality-generating products. These results are explored empirically for the case of greenhouse gas and nitrogen emissions associated with biofuels and petroleum.

1. Introduction

This paper examines optimal externality tax policy in the presence of externalities linked to one another through markets rather than technical production relationships. In lieu of correlations

☆ The research reported here was supported in part by project EBI-007J32 of the Energy Bioscience Institute, award no. CMMI-0400277 from the National Science Foundation, and project no. ILLU-470-316 of the USDA/National Institute of Food and Agriculture. The authors are grateful to Madhu Khanna and Nick Brozović for helpful suggestions. However, the opinions, interpretations, conclusions, and recommendations are entirely the responsibility of the authors and do not necessarily reflect the views of the sponsors.

* Corresponding author. Tel.: +1 720 663 9598; fax: +1 217 333 2312.
E-mail address: shinerain@gmail.com (X. Ren).

0928-7655/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.reseneeco.2010.10.002

between externalities arising through a single production process, we are interested in interaction that arises from market relationships between multiple processes embedded within the economy. We refer to these as "interacting externalities". Our analysis elaborates on the theory of the second best (Lipsey and Lancaster, 1956). That theory states that if one of the Paretian conditions cannot be fulfilled, an optimal solution is likely to require departures from other Paretian conditions. As a corollary, if multiple market failures exist in the economy, eliminating one does not necessarily improve welfare. As described in Bennear and Stavins (2007), multiple market failures can be jointly ameliorating (correction of one market failure ameliorates welfare loss from the other), jointly reinforcing (correction of one market failure exacerbates welfare loss from the other), or neutral (correction of one market failure does not affect welfare loss from the other). With multiple market failures, the interrelationships can become complex, requiring explicit numerical examination to penetrate the web.

The theory of second best has received extensive study in the analytical environmental policy literature. Many studies examine interactions between an environmental externality and pre-existing distortions from labor or capital taxes (*e.g.*, Bovenberg and Goulder, 1996, 1997; Fullerton and Metcalf, 2001; Oats and Schwab, 1988; Parry, 1995, 1997). With varying assumptions about policy instruments and revenue recycling measures, their results differ substantially. For example, a second-best tax on the externality can be either higher or lower than the first-best Pigouvian tax. The optimal environmental tax is a function of multiple terms: (1) a Ramsey term, which represents the revenue-raising function, and (2) the Pigouvian components that relate to each externality (*e.g.*, Bovenberg and Van der Ploeg, 1994; Sandmo, 1975).

Very few studies consider corrective taxes in the presence of multiple simultaneous externalities. Caplan and Silva (2005) introduce the concept of "correlated externalities" to define multiple pollutants jointly produced by a single source that cause differentiated regional and global externalities. Within a multi-stage game theory framework, they find that non-cooperative, command-and-control environmental policies fail to achieve first-best optimality, but a joint permits mechanism can achieve a Pareto optimum. However, different externalities are usually regulated separately, or a single source of multiple externalities is regulated using a single instrument because a joint mechanism could face many political obstacles, especially for a global externality. For example, Peterson (1999) evaluates optimal agricultural land pricing policies considering pollution from agricultural land as well as non-market environmental benefits such as open space. Thus, one source, land, generates both a public good and a public bad. He finds the optimal land subsidy to correct the public goods is not equal the net extra-market regional values of the land amenities. Parry and Small (2005) evaluate the optimal gasoline tax considering externalities from traffic accidents, congestion, and air pollution. In a similar spirit, Khanna et al. (2008) develop a stylized economic model to evaluate the first-best and second-best ethanol policies in the presence of greenhouse gas (GHG) emissions and traffic congestion resulting from transportation uses of fuel. In each of these studies, a simple price-based policy instrument is applied to a single product to correct its multiple externalities.

This paper departs from the previous literature by developing a theoretical general equilibrium model incorporating two environmental externalities resulting from different industries that interact through market demands, in an economy with no government revenue requirement. The levels of the two externalities are determined not only by their individual production technologies, but also by the interaction between their sources in the market. In the model, two taxes are available to control the two environmental externalities, and the resulting revenues are transferred to consumers in lump-sum. Ideally, the tax rates for the two externalities are each set at its first-best level. However, if one of the externalities cannot be corrected fully, *i.e.*, one tax is constrained below the marginal environmental damage of the corresponding externality, the optimal tax rate for the other externality is unclear. Our results indicate that the optimal second-best policy depends on the nature of the market relationships between the two goods whose production causes the externalities. By explicitly modeling the production and market interaction of the two sources, this paper evaluates: (1) the effects of a small change in one tax, whether or not the tax rates are optimal, and (2) the optimal tax for one externality given a distortion from the other externality.

In an effort to illustrate this problem, our analysis is developed in the context of biofuel and fossil fuel production and the associated environmental externalities of greenhouse gases (GHGs) and