Resource and Energy Economics 35 (2013) 60–90

Contents lists available at SciVerse ScienceDirect

Resource and Energy Economics

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

Water quality trading with asymmetric information, uncertainty and transaction costs: A stochastic agent-based simulation

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ARTICLE INFO

Article history:
Received 27 March 2011
Received in revised form 6 September 2012
Accepted 11 September 2012
Available online 24 September 2012

JEL classification:
C63
D47
Q25
Q53

Keywords:
Water quality trading
Agent-based model
Environmental markets
Bilateral negotiations
Clearinghouse
Transaction costs
Asymmetric information
Uncertainty
Bounded rationality
Differential Evolutionary algorithm

ABSTRACT

We examine the efficiency of emissions trading in bilateral and clearinghouse markets with heterogeneous, boundedly rational agents making decisions under imperfect and asymmetric information, and transaction costs. Results are derived using a stochastic agent-based simulation model of agents' decision-making and interactions. Trading rules, market structures, and agent information structures are selected to represent emerging water quality trading programs. The analysis is designed to provide a strong test of the efficiency of trading occurring through the two market structures. The Differential Evolution algorithm is used to search for market trade strategies that perform well under multiple states of the world. Our findings suggest that trading under both bilateral and clearinghouse markets yields cost savings relatively to no trading. The clearinghouse is found to be more efficient than bilateral negotiations in coordinating point–nonpoint trading under uncertainty and transaction costs. However, the market under both structures is unlikely to achieve or even approximate least-cost pollution control allocations. Expectations of gains from water quality trading should, therefore, be tempered.

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http://dx.doi.org/10.1016/j.reseneeco.2012.09.002

1. Introduction

Emissions trading revolutionized air emissions regulations in the United States in the 1990s. The most prominent example is the US cap-and-trade emissions trading scheme for sulphur dioxide (SO_2) emissions established under the 1990 US Clean Air Act Amendments. A new frontier for emissions trading is water quality protection, where the mechanism is commonly referred to as water quality trading (WQT). The US Environmental Protection Agency (EPA) issued policy guidelines for development of WQT programs in 2003 and has invested in the development of markets through funding of demonstration projects and technical assistance (US EPA, 2003, 2007). WQT programs are being considered or are in various stages of development in several states (US EPA, 2011). Prominent examples are the recently initiated nutrient trading programs for point and nonpoint sources in Pennsylvania and the Greater Miami River watershed in Ohio.

The fundamental economic case for emissions trading is that market transactions can achieve pollution targets cost-effectively in markets that environmental regulators can construct without knowing the polluters abatement costs (Crocker, 1966; Dales, 1968; Montgomery, 1972). A key question is whether WQT programs, especially those involving nonpoint sources, can live up to the expectations of regulatory cost savings (Horan and Shortle, 2011; Ribaudo and Gottlieb, 2011). The successful large national cap-and-trade air emissions markets "...work roughly as the textbooks describe" (Joskow et al., 1998). The textbook vision requires that emissions (i) can be accurately metered for each regulated emitter, (ii) are substantially under control of the polluter (i.e., non-stochastic), (iii) that the spatial location of emissions within the market does not affect environmental outcomes, and (iv) that the market is perfectly competitive (Ellerman, 2005).

Nonpoint emissions do not satisfy the first three requirements because they are by definition unobservable at the source, inherently stochastic, and the spatial location of emissions is important to water quality impacts. These factors are not fatal to the development of WQT markets, but they do imply that an optimally designed water quality trading framework that includes nonpoint sources will differ significantly from the textbook model in ways that limit potential cost-savings from a perfectly competitive market (Horan and Shortle, 2011).

The fourth requirement, perfectly competitive markets, is also not characteristic of WQT markets that have been developed to date (Ribaudo and Gottlieb, 2011; Woodward et al., 2002). Perfectly competitive markets require a large number of traders, all with perfect information but without market power, trading a homogeneous good. Regulation of water pollution at small spatial scales (e.g., stream segments, small watersheds) will often imply "thin" markets with limited numbers of potential participants. Traders can be highly heterogeneous in their economic activity, economic size, and contribution to pollution loads. For example, likely participants in a point–nonpoint nutrient trading market could range from small farms to large treatment works. Further, pollution emissions even within a specific category (e.g., nitrogen) can be highly heterogeneous in relevant water quality characteristics (e.g., nitrogen type, time and place of release, etc.). These characteristics eliminate the development of highly organized competitive exchange markets in which traders routinely participate as price-taking buyers or sellers (Woodward et al., 2002). The performance of WQT markets must, therefore, be understood within the context of market structures that are plausible for the problem.

In this paper, we explore the validity of least-cost allocations as a prediction for WQT markets that capture key features of emerging nutrient markets. In addition, we examine the impacts on market outcomes and efficiency of two market structures, transaction costs and selected trading policy parameters. Because of the small number and nascence of point/nonpoint WQT programs, a robust *ex post* assessment cannot be conducted. Our analysis is based on an agent-based model (ABM) that is constructed to simulate the outcomes of trading within a set of trading rules and market structures consistent with developing US markets for nutrient trading between point and nonpoint sources. The agent-based modeling approach stands in contrast to the common use of cost-minimization models for *ex ante* analysis of pollution trading, which assume that markets are perfectly competitive and will achieve the least-cost allocation in equilibrium (Hanley et al., 2007). Agent-based models allow the assumptions of perfect competition to be replaced by more realistic assumptions about individual behavior, information structures, and coordination mechanisms (Duffy, 2006; Roth, 1995, 2002).