Water quality trading experiments: Thin markets and lumpy capital investments

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This article explores how markets for water quality trading are influenced by abatement technology choices. The authors use laboratory experiments to find that thin markets and lumpy capital investments, in the face of technological constraints, imply excessive capital investment and raise abatement costs in trading markets.

Keywords: water quality, trading, markets, technology, choices, economics, experiments

Water quality trading schemes have become popular market mechanisms for improving water quality in recent years. By establishing water rights, trading programs allow facilities with high pollution abatement costs to meet their environmental commitments by purchasing equivalent reductions from other facilities that are able to achieve their reductions at lower cost. However, the empirical success of water quality trading programs has thus far not matched their theoretical appeal. In addition to institutional factors, recent research suggests that point source trading programs are impeded by: (1) “thin” markets with few potential traders; (2) discrete, “lumpy” fixed costs; and (3) the inability of most firms to meet prescribed standards without sizable capital investments. The empirical resource economics literature has yet to fully incorporate these elements that are inherent in real-world water quality markets into modeling approaches.

Markets for water quality are generally “thin”; they are comprised of relatively few participants. In contrast with the celebrated United States sulfur dioxide allowance trading program (involving 3,200 electric generating units nationwide[1]), the number of potential traders in water-quality trading programs is limited by watershed boundaries. A recent review of water quality trading programs suggests that the number of regulated point sources (a single

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identifiable pollution source) in these markets ranges from nine to 79.[2] The number of potential trading partners is further limited by sub-watersheds. For example, although there are 22 wastewater treatment plants (WWTPs) regulated under the Non-Tidal Passaic River Basin Total Maximum Daily Load (TMDL) in New Jersey, U.S.A., the hydrological configuration of the watershed is such that each WWTP has less than 10 available trading partners.[3]

Whereas theoretical presentations of pollution trading are motivated by differences in marginal treatment costs (the cost of treating an extra unit of water), "lumpy" capital costs are a critical feature of point source emissions abatement. In order to reduce abatement costs, substantial investments in capital are necessary since WWTPs are typically designed to treat millions of gallons of water.[4] Recent modeling studies demonstrate that if cost savings are generated through emissions trading, the savings will be largely due to avoided capital costs from plants that purchase permits rather than operating and management cost savings.[3,5]

A related economic factor is that TMDL allocations typically exceed existing WWTP capacity. That is, existing technology is not adequate for achieving the emissions reductions mandated by law. For example, in the Passaic River program, the phosphorus TMDL for wastewater emissions was set at 0.4 mg/L—roughly 80% below the average pre-TMDL wastewater emissions. Only two of the 22 WWTPs in the watershed had the capacity to meet the 0.4 mg/L standard without additional capital upgrades.

Unfortunately, econometric studies of water quality trading are challenged by little cross-sectional and temporal variation in trades. This is a major challenge for empirical researchers to understand the barriers to efficient trading schemes and ways to improve them. As an alternative, we developed a laboratory experiment to investigate the three aforementioned issues.[6] Rather than relying on weak identifying assumptions, the experimental design allows us to create randomness by systematically controlling the sources of variation.

In the experiments, participants act as firm managers in small trading groups composed of six participants who interact in several rounds of trading, which are intended to reflect units of time within a WWTP licensing period. In each round, individual firms are assigned an income and generate a baseline of eight emissions units. The trading group must reduce pollution by 24 units, meaning that, without trading, each of the firms must incur the cost of abating four units. At the start of each round, participants decide whether to pay a fixed cost to upgrade from a conventional "high cost" (HC) abatement technology to a "low cost" (LC) technology that reduces their marginal costs of abatement for all subsequent rounds. Following the technology decision, four emissions permits are allocated to each firm and participants interact through a computerized double-auction trading program where the permits can be purchased and sold.

The heterogeneity (or diversity) in abatement costs between firms is driven by the number of firms that choose to invest in the LC abatement technology. Given the heterogeneity in costs, trading can reduce aggregate compliance costs by allocating more abatement to the LC firms. Given our experimental parameters, the cost-minimizing way of abating 24 units is to have two LC participants, each abating six units and selling two emissions permits, and four HC participants who each abate three units and buy one permit. Importantly, the heterogeneity induces variation in abatement costs, thus providing gains to trading among participants and econometric identification of relevant phenomena.

Several experimental treatments are undertaken to explore the relationships between permit prices, capital upgrades, and limitations in abatement technology. Each treatment is characterized by the initial number of firms with HC technology (either four or six), whether HC firms can upgrade to the LC technology, and if HC firms are limited in the amount of emissions they can abate. Varying the number of HC firms allows us to explore whether over–compliance is due to coordination problems between participants. Controlling the opportunity to upgrade enables the investigation of whether the distribution of buyers (HC) and sellers (LC) and the threat of upgrades influence the price of permits. Placing a cap on abatement capacity for HC firms controls for whether technological constraints affect trading and upgrade behavior.

Our main results show significant over-investment when firms are given the opportunity to upgrade. This is consistent with real-world observations of over-compliance in watershed-level pollution trading programs.[7,8] In particular, the results suggest that over-investment is not driven by the inability of firms to coordinate on the efficient number of upgrades. The average number of LC firms at the end of a session is not significantly different when groups begin with the efficient number of LC firms compared to when there are zero LC firms initially.

Market outcomes are affected by the presence of technological constraints. In treatments with constraints, permit sellers (LC participants) have greater market power since the HC participants must purchase at least one permit or face a large penalty. Our results show that in treatments where such constraints are imposed, permit prices are significantly higher and there are a greater number of upgrades. Upgrade decisions are positively correlated with measures of risk aversion, suggesting that risk-averse participants are especially likely to upgrade from HC to LC so as to avoid the potential of a penalty or having to purchase a high priced permit.

Taken together, our experimental results demonstrate that thin markets and lumpy capital investments, in the face of technological constraints, imply excessive capital investment and raise abatement costs in trading markets. When considering the design of emissions trading markets, policymakers should pay close attention to these real-world complications and how they may affect incentives for abatement and the costs of compliance.

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