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Efficiency of an emissions payment system for nitrogen in sewage treatment plants – A case study

J. Mikael Malmaeus*, Mats Ek, Linda Åmand, Susanna Roth, Christian Baresel, Mikael Olshammar

IVL Swedish Environmental Research Institute, P.O. Box 210 60, SE-100 31 Stockholm, Sweden

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ABSTRACT

An emissions payment system for nitrogen in Swedish sewage treatment plants (STPs) was evaluated using a semi-empirical approach. The system was based on a tariff levied on each unit of nitrogen emitted by STPs, and profitable measures to reduce nitrogen emissions were identified for twenty municipal STPs. This was done through direct involvement with the plant personnel and the results were scaled up to cover all treatment plants larger than 2000 person equivalents in the Swedish tributary areas of the Kattegat and the Baltic Proper. The sum of costs and nitrogen reductions were compared with an assumed command-and-control regulation requiring all STPs to obtain 80% total nitrogen reduction in their effluents. Costs for the latter case were estimated using a database containing standard estimates for reduction costs by six specified measures. For both cases a total reduction target of 3000 tonnes of nitrogen was set. We did not find that the emissions payment system was more efficient in terms of total reduction costs, although some practical and administrative advantages could be identified. Our results emphasize the need to evaluate the performance of policy instruments on a case-by-case basis since the theoretical efficiency is not always reflected in practice.

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1. Introduction

Market-based policy instruments aimed at pollution control are generally regarded to be more economically efficient than traditional command-and-control regulations (Hahn and Stavins, 1991; Jaffe and Stavins, 1995; Requate, 2005; Lawrence and Parry, 2008). Many different types of market-based instruments exist (see Stavins, 2001; Sterner and Hammar, 2010 for a review) with the common feature being market incentives encouraging firms or individuals to reduce emissions at their own choice. A classic example is provided by so-called Pigouvian taxes on emissions, where the aim of the tax is to influence the behaviour of firms rather than to punish polluters. Under ideal conditions such a tax will allow agents with low reduction costs to invest more in pollution control while other agents may choose to invest less, and total emissions from all agents can be kept below a desired level. In theory, optimal efficiency occurs when the tax rate is equal to the average marginal cost of emissions reduction at the critical level of emissions.

There also exist several types of trading systems where agents with low abatement costs may sell emission reductions to agents with high abatement costs. With perfect knowledge, a Pigouvian tax and a trading system will obtain the same optimal reduction. Apart from economic efficiency with respect to abatement costs, market-based instruments may also be practically efficient with low administrative costs compared to a system where permits are based on individual negotiation. Market-based instruments are also believed to provide permanent incentives for adoption of new technologies, as long as sufficiently inexpensive abatement technologies can be found (Jaffe and Stavins, 1995).

In a command-and-control system there is no incentive for individual firms to perform better than the required emission standard set by the authorities, and hence no incentive to develop or adopt new technologies to reduce emissions unless they are cost-reducing. On the other hand, command-and-control systems have the advantage of achieving their objectives with greater certainty than some market-based policy instruments. Several empirical studies have compared command-and-control measures and market-based instruments, with respect to abatement incentives, cost effectiveness and emissions reductions. One example from Sweden is the NO_x fee,

* Corresponding author.
E-mail address: mikael.malmaeus@ivl.se (J.M. Malmaeus).

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implemented in 1992 on energy production. The system had very low administrative costs and evaluations have proven it to be a cost-effective complement to emission permit conditions (SEPA, 2004) and also encouraged development of better technologies for emission reductions (Sterner and Turnheim, 2009). The phase out of lead in gasoline in U.S. petroleum refineries during the 1970s and 1980s was evaluated by e.g. Kerr and Newell (2003) and Kerr and Maré (1997). The cost effectiveness of the tradable permit system was considered to be high and econometric analysis suggests that firms had a higher probability of adopting new technology during the periods with market based instruments than with performance standards. Another example from the U.S. concerns sulphur dioxide allowance trading, which started in 1995. Studies by Carlson et al. (2000) and Stavins (1998) conclude that abatement costs were significantly less than what they would have been in absence of trading.

Harrington and Morgenstern (2004) compared six environmental problems where the United States and a European country had chosen different kinds of policies. They found that market-based policy instruments generally reduced the overall abatement costs compared to command-and-control regulations, but that to gain acceptance the revenue raised by the authorities had to be reimbursed to the firms. Other empirical studies include Kolstad (1986) who found that economic incentives were far more cost-efficient than command-and-control regulations in reducing air pollution in the United States. Thomas (1995), on the other hand, compared actual emission taxes on industrial water pollution in France with theoretically optimal taxation and found that taxation in general was too low to be effective. Likewise, Mickwitz et al. (2008) investigated the actual performance of various policy instruments in promoting technological development in Finnish industries and found little support for the general claim that taxes and regulations stimulate innovation and transmission of environmentally friendlier technologies. In all, these results indicate that the performance of market-based policy instruments should be evaluated on a case-by-case basis since all markets apparently have their own peculiarities.

In this work we present results from a semi-empirical case study comparing an emission payment system for nitrogen reductions with a command-and-control regulation prescribing a specified wastewater treatment efficiency. Projections based on an inquiry with around 20 sewage treatment plants (STP) assuming an emission payment system were compared with estimated nitrogen reductions under a command-and-control regulation assuming measures selected from a database containing a large number of Swedish plants. The study was designed to obtain the national goal for nitrogen reductions according to the Baltic Sea Action Plan (HELCOM, 2007) where the STPs have been committed to fulfil a specified reduction target. According to the Swedish implementation plan, nitrogen emissions from treatment plants should be reduced by 3000 tonnes. Current nitrogen emissions from treatment plants treating a load corresponding to more than 2000 person equivalents (pe) amount to about 17 400 tonnes or 7400 to the Baltic Proper (SCB, 2010). One pe is equal to 70 g BOD per person, where BOD is biological oxygen demand.

In the end we compare the cost for reaching the target following either of the two strategies. We also discuss the pros and cons of a refunded emission payment system which was suggested by the Swedish Water and Wastewater Association, and the role of policy instruments for promoting technological development and investment. The objective of the study is to evaluate the difference in performance between a market-based system and a command-and-control regulation in a real-world situation.

2. Methods

2.1. The emission payment system

The emission payment system evaluated in this study is based on a tariff levied on each unit of nitrogen emitted by STPs. The key issue is what effect this system would have on Swedish nitrogen emissions from treatment plants processing more than 2000 pe assuming three different tariff levels (1 SEK ≈ € 0.11):

25 SEK per kg N
75 SEK per kg N
200 SEK per kg N

These three cases are considered to provide a realistic range of levels to allow an evaluation of emission reductions resulting from this payment system that may compare to the Swedish obligations according to the Baltic Sea Action Plan. The levels are based on previous estimates of marginal costs to reduce nitrogen in Swedish sewage treatment plants (Ek et al., 2009). The total fee paid by an individual STP is thus calculated as:

$$C_i = t\, e_i \tag{1}$$

where C_i is the total fee of plant i, t is the tariff level and e_i is the amount of nitrogen emissions from plant i. If such a system would be employed in Sweden the annual monetary turnover (ΣC_i) would range between 435 million SEK and 3500 million SEK. The idea is to repay these fees back to the treatment plants according to a refunding scheme, where agents with a high level of nitrogen reduction will receive more than agents with a low reduction level so that investments in treatment technology is further stimulated. However, we did not specifically investigate the effect of this refunding scheme and hence we do not specify the details here.

2.2. Case study

An electronic survey was sent out to and returned by twenty municipal STPs located in southern and central Sweden, with emissions directly or indirectly affecting the Baltic Proper. The inquiry contained detailed questions regarding treatment technology (pre-treatment, type of biological treatment, type of nitrogen treatment in main stream and reject water, sludge treatment), nutrient levels in different internal streams and nutrient emissions (COD, BOD, nitrogen and phosphorus) during 2009. The returned information was compiled and sent out to the treatment plants and discussions over telephone were carried out individually with each plant, concerning possible measures (already planned, under construction or feasible in the future) to reduce nitrogen emissions including cost estimates. Information about treatment processes for each plant is provided as Supplementary online appendix.

The selection of feasible measures was based on the expertise available at the STPs and within the research group, and was generally confined to standard measures commonly applied in Swedish STPs. Cost calculations were generally based on 6 per cent interest rate, 10 years depreciation time for machinery and 30 years for buildings. We assumed a cost of 4 SEK per kg BOD as external carbon source and 1 SEK per kWh of electricity. In addition, several larger plants already had cost estimates for various installations providing specific costs for nutrient reductions. For some measures standard estimates from earlier studies were used (Ek et al., 2009). The most cost efficient measures often included external carbon additions in existing pre-denitrification or post-denitrification. Other measures considered included new installations of post-denitrification, improved separation between aerated and non-

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