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Can integrated control strategies for multiple emissions enhance cost-efficiency in environmental policy? Evidence from Sweden

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ABSTRACT

The aim of this paper is to clarify the magnitude of the sub-optimization cost associated with separate control strategies for compliance with the Swedish environmental quality objectives. The marginal reduction costs are estimated using a separate and an integrated version of a deterministic linear programming model. To investigate whether the accuracy of the data is decisive for the result of this study, an extensive sensitivity analysis that deals with both the disparity in discount rates in data and the different types of measures, is carried out in four steps. It can be concluded that the results are robust for possible and probable faults in data. The main findings are that there are no substantial sub-optimization costs for separate control strategies for CO_2, NO_X and SO_2, but an integrated action strategy could imply enhanced cost-efficiency in reductions of VOC and particles.

1. Introduction

The issue of possible synergies in emission reductions is currently of political interest, for instance the EU process Clean Air For Europe (CAFE) handle several emissions (http://ec.europa.eu/environment/air/cafe/). At the Swedish national level, there are 16 national environmental quality objectives (www.miljomal.nu). For some emissions the measures that can be undertaken by households, firms, and the public sector are in common. Measures that target fuel consumption reduce CO_2 emissions as well as a number of pollutants and technical abatement measures affect several pollutants simultaneously. According to LeChantilier's principle and the joint production theory,[1] accounting for correlation in emission reductions should reduce the cost for each emission reduction (Baumgärtner et al., 2003; Burtraw and Toman, 2000; Gravelle and Rees, 1992; EIA, 2000).

If the external cost of all emissions could be easily internalised by taxes no integrated control strategies would be needed since the market would solve the problem. But there are emissions that are difficult to tax, e.g. NO_X emissions from vehicles. The control strategies to achieve the Swedish environmental objectives consist of a mixture of taxes, regulation and subsidies evaluated emission by emission (SGB, 1997/1998; SGB, 2000/2001). For instance, the carbon dioxide (CO_2) emissions from households and transportation are taxed, while these emissions from manufacturing and from heat production are controlled by both a lower tax and emission trading. Emission of volatile organic compounds (VOC) and particles are controlled by regulation. The purpose of this paper is to investigate the possibilities of enhancing the cost-efficiency of Swedish environmental policy by introducing integrated control strategies for simultaneous reduction of major emissions into air. The magnitude of the possible efficiency gain for Sweden is an empirical issue. So the

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[1] The concept originates in business administration but has recently also emerged in the field of ecological economics. Related concepts in the literature on environmental policy are secondary or ancillary benefits.

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sub-optimization cost of separate emission control is estimated by comparing the marginal abatement cost assessed with an integrated and with a separate approach. A linear programming model is applied to data on 78 measures aiming at reducing emissions in Sweden. The data contain engineering estimates of long-term annual cost and reductions of CO_2, nitrogen oxides (NO_X), sulphur dioxide (SO_2), VOC, and particles. Since the data are plagued by uncertainty in several respects, a sensitivity analysis is undertaken to evaluate what data are decisive for the results.

The paper consists of six sections. Following this introduction, Section 2 presents the data on emission-reducing measures to be used in the study. Section 3 describes the linear programming model for calculating marginal costs of emission reductions. The results are presented and discussed in Section 4, followed by a sensitivity analysis in Section 5. The paper closes with conclusions in Section 6.

2. Data

In this paper we estimate a marginal abatement cost function at a national level. Abatement activities, at a national level, are called measures. Measures are specific activities aiming at reducing emissions and undertaken by households, firms, or the public sector. A few examples of measures are increasing the load factor for long road transports, car pooling, retrofit installation of catalysts on working tools, extra insulation of attics, and installation of accumulator tanks for wood boilers. All measures and descriptive statistics are presented in Appendix A.

The data are engineering data, collected in the year 1999 for a parliamentary committee. The measures to reduce the emissions from transportation are based on the MaTs collaboration,[2] the measures pertaining to off-road machinery were provided to the committee by the Swedish Environmental Protection Agency, and all measures concerning energy consumption and transformation were provided by the Swedish Energy Agency. All these national authorities used consultants to collect the data. Finally, the measures to reduce emissions from manufacturing were provided directly to the committee by consultants.

For each measure the data specify national approximations of the long-term annual cost and the effect on emissions of CO_2, NO_X, SO_2, VOC, and particles, since the emission effects and the cost for every heterogeneous household or firm are unknown. The long-term annual cost (c_i) of measure i is defined as the sum of an annuity of the total investment cost (AI) and the annual operating cost (OC), defined as the difference between the operating cost with the original equipment and the operating cost after the measure has been implemented. Hence:

$$c_i = \mathrm{AI} + (\mathrm{OC}_{\text{Original equipment}} - \mathrm{OC}_{\text{New equipment}}) \quad (2.1)$$

[2] MaTs MiljöAnpassat TransportSystem, i.e. Environmental adopted transportation system, a project carried out in a collaboration of the Swedish Environmental Protection Agency, the National Road Administration, the National Rail Administration, Swedish Maritime Authorities and Swedish Civil Aviation Administration in the late 1990s.

For some measures the operating cost part of (2.1) is negative, indicating that investments in more efficient technology can reduce both emissions and the operating cost. The total annual costs reported in the data are either:

- $c_i > 0$, in which case it is uncertain whether the operative expenses increase or decrease when the investment is made,
- $c_i = 0$, in which case it is assumed that the investment cost is cancelled out by reduced operative expenses but nothing is known about the magnitude of the investment cost,
- $c_i < 0$, i.e. the reduction in operating cost more than outweighs the unknown annual investment cost.

The discount rate used is 12% for the 23 measures related to energy transformation and consumption, and 4% for the remaining 55 measures related to manufacturing, transportation, and off-road machinery. The Swedish Energy Agency uses the higher discount rate, as it is more plausible for energy related investments. Unfortunately, enough information to correct for this discrepancy has not been obtained from any of the consultants involved in the data collection, even though inquiries have been made about it. So in all cases, a couple of ad hoc assumptions are required to establish the magnitude of the investment cost and the change in operating cost. In the third part of the sensitivity analysis assumptions are made about the proportion of c_i that constitutes the operating cost, in order to equalize the discount rate for all measures. Several other pieces of information, such as implementation costs, are also left out in the data. Neither the costs for planning and evaluation of different investment options nor the social cost of operating the new equipment, i.e. loss of time or comfort, are included.

There are 78 measures in this study to reduce emissions within Sweden, of which 14 are characterised as measures that reduce fuel or energy consumption through behavioural changes, 10 as technological efficiency improvements by investments in new technology, 44 as technical abatements by investments in abatement technology, and 10 as structural changes for instance change of fuel or travel mode. The measures that reduce fuel or energy consumption are important for the reduction of CO_2 emissions, while the particle emissions increase. The NO_X, SO_2 and VOC emissions are only marginally affected. The energy efficiency improvements have a great impact on the VOC emissions, but they are on average less important for CO_2 reduction than the former category. The mean energy efficiency improvement reduces the particle emissions, but half of the improvements increase the particle emissions. The total reduction possibilities for the technical abatement measures are substantial for all emissions but CO_2. The measures that imply structural changes mainly target CO_2 emissions.

The mean costs of the measures that reduce fuel or energy consumption and the energy efficiency improvements are negative owing to reduced fuel costs. Hence, some of the measures that target fuel consumption and some of the energy efficiency improvements could be undertaken for economic profit, even without any further requirements for emission control. Similar results have been reported in other studies (Hammitt, 2000; Nijkamp et al., 2001; Velthuijsen,