Resource and Energy Economics 30 (2008) 475–491

Contents lists available at ScienceDirect

Resource and Energy Economics

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

The effect of uncertainty on pollution abatement investments: Measuring hurdle rates for Swedish industry☆

Åsa Löfgren [a], Katrin Millock [b,*], Céline Nauges [c]

[a] Department of Economics, Göteborg University, P.O. Box 640, SE 405 30 Göteborg, Sweden
[b] Paris School of Economics, CNRS, Centre d'Economie de la Sorbonne, Université Paris 1, 106/112 Boulevard de l'Hôpital, 75647 Paris Cedex 13, France
[c] Toulouse School of Economics, LERNA-INRA, Manufacture des Tabacs, 21 Allée de Brienne, 31000 Toulouse, France

ARTICLE INFO

Article history:
Received 14 January 2008
Received in revised form 17 June 2008
Accepted 24 September 2008
Available online 9 October 2008

Keywords:
Option value
Oil price uncertainty
Abatement investment
Sulfur emissions
Pulp and paper industry
Energy and heating sector

JEL classification:
C33
D81
O33
Q48
Q53

ABSTRACT

We estimate hurdle rates for firms' investments in pollution abatement technology, using ex post data. The method is based on a structural option value model where the future price of polluting fuel is the major source of uncertainty facing the firm. The empirical procedure is illustrated using a panel of firms from the Swedish pulp and paper industry, and the energy and heating sector, and their sulfur dioxide emissions over the period 2000–2003. The results indicate that hurdle rates of investment vary from 2.7 to 3.1 in the pulp and paper industry and from 3.4 to 3.6 in the energy and heating sector depending on econometric specification.

☆ Financial support from Mistra's Climate Policy Research Program (CLIPORE) is gratefully acknowledged. We thank seminar participants at CARE-Université de Rouen, CORE-Université catholique de Louvain, and participants at the Conference on Environment, Innovation, and Performance, held in Grenoble (France) in June 2007, for useful comments on earlier versions of this paper. We also thank two anonymous reviewers for very insightful comments that have improved the paper.

* Corresponding author. Tel.: +33 1 44 07 82 60; fax: +33 1 44 07 82 31.
E-mail addresses: asa.lofgren@economics.gu.se (Å. Löfgren), katrin.millock@univ-paris1.fr (K. Millock), cnauges@toulouse.inra.fr (C. Nauges).

0928-7655/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.reseneeco.2008.09.002

1. Introduction

A polluting firm usually faces a choice between different abatement possibilities ranging from simple end-of-pipe technologies, that reduce emissions at the end of the production line, to highly complex clean technology systems that necessitate production process changes. Engineering studies normally show a range of feasible investment opportunities (with positive net present values), nevertheless, firms do not invest at the predicted level. Several explanations have been advanced to explain this apparent puzzle, including errors in the measurement of costs, heterogeneity in discount rates or, still, market failures (see for example Hausman, 1979; Sutherland, 1991; Jaffe and Stavins, 1994).

Here, we develop a structural approach to measure the impact of uncertainty in the future price of polluting fuel on a firm's decision to invest in abatement technology. The proposed model will assume that the abatement investment is irreversible, since the equipment normally is firm-specific and has little re-sale value. Fuel use is a major source of air pollution and a rational firm facing environmental and energy taxation would normally consider both the pollution impact and any impact on the energy bill in deciding whether to undertake an abatement investment. Previous research on the U.S. steel industry, for example, showed that higher fuel prices had a significant positive impact on the decision to adopt fuel-saving technologies with a potential to reduce pollution (Boyd and Karlson, 1993).

Choice of irreversible investment under uncertainty relates directly to the option value theory (McDonald and Siegel, 1986; Dixit and Pindyck, 1994), which predicts that firms may delay investment because the value of waiting to resolve uncertainty exceeds the value of owning the asset during the waiting period. Several empirical applications of the option value theory of investment have been developed in order to explain the slow adoption of technologies that reduce emissions and the environmental impact of production.[1] Most of these use simulation techniques, though, and there are few ex post studies on investment data. The main contribution of this paper is to estimate hurdle rates[2] for abatement investments from a structural option value model, using ex post data from the Swedish energy and heating sector and pulp and paper industry.

Following Dixit and Pindyck (1994) we derive the threshold condition on the price of the polluting fuel for which a firm facing uncertainty will decide to invest in a new abatement technology. As in Harchaoui and Lasserre (2001), the proposed estimation procedure is based on the fact that this threshold condition holds at the time of the investment. Whereas Harchaoui and Lasserre (2001) provide a test of the option value theory in a more general framework, we instead measure hurdle rates for Swedish abatement investments under the assumption that the real option theory is relevant for all firms in our sample, and we discuss some of the potential policy implications of our results. We propose two approaches to measure hurdle rates: first, through direct computation of individual hurdle rates for each firm that has invested, second, through an econometric estimation that controls for random measurement error. Necessary data are firm characteristic data (such as fuel consumption, input prices, and output) before and after the investment took place as well as information on the actual capital costs of investment. The model is adapted to air pollution from fuel use and the econometric procedure is illustrated using a panel of firms from the Swedish pulp and paper industry, and the energy and heating sector and their SO_2 emissions from 2000 to 2003. The Swedish energy and heating sector is the primary fuel-consuming sector in Sweden, representing over 30% of total fuel consumption (in 2003), but the pulp and paper industry is also a major user of fuels (10% of total fuel consumption in 2003). Fuel costs account for around 20% of the sales value in the energy and heating sector, and 2% in the pulp and paper industry, on average, so the model's assumption of the main uncertainty being the one surrounding the future price of polluting fuel is particularly relevant for the

[1] We only consider sunk costs of investment and economic uncertainty. Kolstad (1996) and Pindyck (2000, 2002) analyze the more general social trade-off between sunk costs and foregone benefits as well as economic versus ecological uncertainty.

[2] The hurdle rate is the multiplier of the level of the polluting fuel price that triggers the investment according to a standard net present value calculation.