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Profit-maximizing R&D in response to a random carbon tax

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Abstract

This paper determines a firm's profit-maximizing R&D response to an uncertain carbon tax, for two different R&D programs: cost reduction of low carbon energy technologies and emissions reductions of currently economic technologies. We find that optimal R&D does not increase monotonically in a carbon tax. R&D into alternative technologies increases only if the firm is flexible enough; R&D into conventional technologies first increases then decreases in a carbon tax. Firms that are very flexible may increase R&D into alternative technologies when the uncertainty surrounding a carbon tax is increased; otherwise firms will generally decrease R&D investment in uncertainty.

JEL Classification: D81; G11; Q55

Keywords: Profit-maximization; Research & development; Uncertainty; Investment

1. Introduction

A major topic in the discussion surrounding climate change policy is the role of induced technical change—technological innovation induced by climate policies. Another central issue when considering optimal policies for global climate change is the presence of uncertainty and learning about climate damages. There is much written about the impact of uncertainty on optimal abatement. The results from this literature indicate that the optimal response is to go slow,[1]

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[1] See, for example, Baker (2005); Keller et al. (2004); Ulph and Ulph (1997) and Kolstad (1996). The results are not, however, absolute. For example, both Webster (2002) and Gollier et al. (2000) show that the results can be reversed under certain conditions.

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and policy makers in the U.S. seem to have taken this to heart, and are going slow indeed. Thus, there are no carbon-related policies to induce technical change at this time. Nevertheless, we see at least some firm-supported R&D: some firms are responding to the possibility of future policies.

In this paper we examine a firm's optimal R&D investment in response to a future uncertain carbon tax. A common assumption in the induced technical change literature (Nordhaus, 2002; Buonanno et al., 2003; Goulder and Mathai, 2000; Popp, 2004a, b) is that a carbon tax will induce environmental R&D. Nevertheless, Sue Wing (2003) has shown that this may not be true in a general equilibrium setting, and Farzin and Kort (2000) show that the optimal level of environmental R&D can be non-monotonic in an emissions tax. We analyze these findings in a general micro-economic framework and find that they depend on the specific R&D program: all energy/environmental R&D is not alike. Moreover, a rational, forward-looking firm considering long-term R&D projects should base its decisions on beliefs about future policies, rather than simply react to current policies. Thus, understanding the role of uncertainty and learning is key to understanding firms' R&D investments. The motivation for this paper is three-fold: (1) to provide guidance to firms on the best way to respond to uncertainty about climate policy; (2) to influence the way that induced technical change is modeled in Climate-Economy models; (3) to inform climate technology policy.

We show that broad categories of technical change can be represented as changes in the relative prices the firm faces for its inputs. An application of Hotelling's Lemma then shows that the marginal benefits of R&D are proportional to well understood quantities. Namely, the marginal benefits of R&D into alternative technologies[2] are proportional to the unconditional demand for alternative energy inputs; the marginal benefits of R&D into reducing emissions of conventional, fossil-fuel technologies are proportional to the total carbon tax expenditures.

We find, for both programs, that the optimal investment into R&D can decrease with increases in a carbon tax. Investment into alternative technologies will increase monotonically with a carbon tax—if the firm is flexible enough. Investment into conventional technology will first increase and then decrease in a carbon tax, unless it is optimal to invest in carbon capture and sequestration of 100% of the emissions from a fossil fuel burning technology. Additionally, we analyze how an increase in the riskiness (in Rothschild and Stiglitz (1970) sense of a mean-preserving spread) of the carbon tax impacts optimal firm-level R&D spending. We find that, usually, R&D into conventional technology will decrease in uncertainty. On the other hand, R&D into alternative technology may increase in risk, if the firm is very flexible and if the increase in risk increases the probability that the carbon tax will be high enough to make non-carbon energy widely competitive. Otherwise, firms will decrease investment in alternative technologies as risk increases.

Most of the literature on induced environmental technical change uses an abstract abatement cost function, and makes assumptions about how technical change will impact this cost function (Downing and White, 1986; Fischer et al., 2003; Goulder and Mathai, 2000; Jung et al., 1996; Milliman and Prince, 1989; Montero, 2002; Parry, 1998). We illustrate, however, that even simple assumptions on how R&D impacts the production function have complex impacts on the marginal cost of abatement, impacts that depend on the

[2] For example, programs to lower the cost of solar PVs or wind generation.