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Timing of innovation policies when carbon emissions are restricted: An applied general equilibrium analysis

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ABSTRACT

This paper studies the timing of subsidies for emissions-saving research and development (R&D) and how innovation policy is influenced by a carbon tax. We develop a dynamic computable general equilibrium (CGE) model with both general R&D and specific emissions-saving R&D. We find two results that are important when subsidizing emissions-saving R&D in order to target inefficiencies in the research markets. First, the welfare gain from subsidies is larger when the carbon tax is high. This is because a high carbon tax raises the social value of the emissions-saving technology and that this increase in value is not fully appropriated by the private firms. Secondly, the welfare gain is greater when there is a falling time profile of the rate of subsidies for emissions-saving R&D, rather than a constant or increasing profile. The reason is that knowledge spillovers are larger in early periods.

1. Introduction

In the coming decades, industrialized countries will have to face large reductions in emissions of greenhouse gases (GHGs) to curb anthropogenic interference with the global climate system. One expects that a variety of policy measures will be needed to achieve the cuts in GHGs. Most likely these will include a cap-and-trade system that gives a price to carbon emissions, like the European Trading Scheme, and a policy to improve clean energy technology like power production with carbon capture and storage (CCS). The most cost-efficient single policy to reduce emissions is an environmental policy

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that directly targets emissions, such as a tax or cap-and-trade system.[1] However, in the presence of induced technological change and market failures in R&D, a combination of environmental and innovation policies may be more cost effective.[2] Jaffe et al. (2005) argue that market failures associated with environmental pollution interact with market failures associated with the innovation and diffusion of new technologies. These combined market failures provide a strong rationale for a portfolio of public policies to foster emissions reductions as well as the development and adoption of environmentally beneficial technology.

Key arguments for subsidizing innovation activities are external knowledge spillovers from previous R&D and love of capital variety in demand, combined with inefficiencies arising from imperfect competition in the capital variety market.[3] The market inefficiencies imply that the private returns from R&D are lower than the social returns, which leads to underinvestment in R&D. This underinvestment is the rationale for subsidizing R&D activity. There are several papers with R&D driven technological change that include specific policies to target inefficiencies in innovation markets in an environmental context.[4] A typical policy is providing a constant subsidy for R&D. However, the optimal subsidy rate would not necessarily be constant over time. Hart (2008) finds that the gap between social and private returns from R&D investments may vary across time along a transition path. He implements optimal second-best carbon taxes, which may be higher than the Pigouvian level outside the balanced growth path in order to encourage investment in emissions-saving technology at the expense of ordinary production technology. Hart (2008) does not study the implication this has for first-best environmental R&D subsidies.

Our contribution to the literature is two-fold. First, we analyze the timing and impact of emissions-saving R&D subsidies when future emissions are limited, e.g. by a binding international agreement implemented via a carbon tax. In particular, we ask two questions. First, we ask whether the welfare gains from emissions-saving R&D subsidies are larger when the future carbon tax is high. Raising the carbon tax causes an increase in the social value of R&D in emissions-saving technologies. This may only partly be captured by private firms and thus change the welfare gains from subsidizing R&D. Secondly, we ask if welfare gains are influenced by how emissions-saving R&D subsidies are distributed across time. If knowledge spillovers vary over time, there is reason to believe that R&D subsidies should vary over time. This timing problem of R&D subsidies has not received much attention in the literature, to our knowledge.

Our second contribution to the literature is that we develop a computable general equilibrium (CGE) model with endogenous technological change based on the Romer (1990) approach with decreasing returns to new ideas (Jones, 1995). The model is dynamic with forward looking agents where technological change stems from new patents produced by profit-maximizing R&D firms. Emissions of GHGs are accounted for in the model, and a carbon tax influences the direction of technological change towards either general R&D or emissions-saving R&D. In addition, we take into consideration the high reliance of small, open economies on externally given international prices, competition, and growth. The case of a small, internationally exposed economy is exemplified by the Norwegian economy.

Our model falls into the tradition of several CGE model developments with induced technological changes during the recent decade; see Gillingham et al. (2008) and Wing (2006) for overviews. However, most of the CGE models with induced technological change and carbon policies are based on ad hoc modelling of the innovation process. The model closest to ours is Otto et al. (2007).[5] In their model for the Netherlands the innovation process is explicitly modelled as R&D based growth of the Romer (1990) type with imperfect competition in the markets for new technologies embodied in variety capital, as in our model. Contrary to ours, they treat productivity growth as entirely domestically driven.

[1] See Schneider and Goulder (1997), Popp (2006), Parry et al. (2003).

[2] See Schneider and Goulder (1997), Goulder and Schneider (1999), Rosendahl (2004), Fischer and Newell (2008), Otto et al. (2008).

[3] See Jones and Williams (2000).

[4] See Gillingham et al. (2008) for a survey of induced technological change in climate policy modeling.

[5] See also Otto et al. (2008) and Otto and Reilly (2008).