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Climate policies and learning by doing: Impacts and timing of technology subsidies

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Abstract

We study the role of technology subsidies in climate policies, using a simple dynamic equilibrium model with learning by doing. The optimal subsidy rate of a carbon-free technology is high when the technology is first adopted, but falls significantly over the next decades. However, the efficiency costs of uniform instead of optimal subsidies, may be low if there are adjustment costs for a new technology. Finally, supporting existing energy technologies only, may lead to technology lock-in, and the impacts of lock-in increase with the learning potential of new technologies as well as the possibilities for early entry.

JEL Classification: D58; H21; O30; Q42

Keywords: Climate change policies; Computable equilibrium models; Learning by doing; Subsidies; Timing

1. Introduction

Dealing with the climate change problem is a long-term issue, and the importance of developing and commercializing carbon-free energy technologies has been highlighted over the last years. The process of innovation and learning, and its connection with climate policies, is being extensively studied both theoretically and numerically, see, e.g., Jaffe et al. (2002) for an overview. However, the question remains how to combine carbon taxes with innovation subsidies within an intertemporal framework, when several carbon-free technologies with different characteristics may come into play. In this paper we examine how the prospect of a future carbon-free and profitable

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energy technology may affect climate and innovation policy, taking into account that existing carbon-free energy technologies are costly but exposed to external learning effects.

Existing literature has clearly shown that climate policies lead to induced technological change (ITC). The main argument is that public policies may affect the prices of carbon based fuels, which in turn affect incentives to undertake research and development (R&D) aimed at bringing alternative fuels to market earlier at a lower cost and/or at a higher capacity (e.g., Goulder and Schneider, 1999; Buonanno et al., 2000; Popp, 2004a). These low-carbon products could represent existing or entirely new energy services. In addition, higher fuel prices may induce new production methods that require less of any kind of fuel. Technology may also improve through learning-by-doing (LBD) (Arrow, 1962), i.e., producers gain experience in using alternative energy services or energy-conserving processes (see, e.g., Rasmussen, 2001; van der Zwaan et al., 2002; IEA, 2000). Stimulation of such activities, either directly through subsidies or indirectly through taxing competing activities, may therefore influence the technological process. In Gerlagh and Lise (2005) both R&D and LBD are considered in a partial equilibrium model, focusing on the transition from fossil fuels to carbon-free energy sources, stimulated by carbon taxes.

The fact that climate policies affect technological change, gives feedback effects to the optimal choice of policy, in at least two different ways. The first is the implications for the *timing* of the abatement and the optimal carbon tax path. Wigley et al. (1996) examine the optimal timing of CO_2 emission abatement if there is a long-term stabilization goal of atmospheric CO_2 concentration. They conclude that, in general, total discounted abatement costs are minimized if the bulk of abatement takes place in the more distant future rather than soon. There are several reasons for this, but one reason is technological progress. In their model, new energy–efficiency technologies will be discovered and developed exogenously over time, thus making abatement cheaper in the future. Other authors argue that this may not be true if technological change is not autonomous but is instead induced by certain activities like R&D investments or LBD. Abatement today may provide a catalyst for new technologies that may reduce future costs (see, e.g., the discussion in Schneider and Goulder, 1997). Goulder and Mathai (2000) study the timing problem for both R&D based and LBD based knowledge accumulation, under both a cost-effectiveness and cost–benefit criterion. While they do not study the effects of replacing autonomous technological change by ITC, they conclude that the impact of ITC in addition to autonomous technological change on the optimal abatement path, varies with the representation of technological change. Under R&D, ITC shifts some abatement from the present to the future, while under LBD, the impact of ITC is ambiguous. Nevertheless, without spillover effects, ITC always implies a lower time profile of optimal carbon taxes. However, as noted by Rosendahl (2004), the optimal carbon tax could rise if some of the learning effects are external to the firm. Finally, Manne and Richels (2004) find that including LBD does not significantly alter the conclusions of timing of emissions abatement from previous studies that treated technology costs as exogenous. However, abatement costs can be substantially reduced.

A second important question under ITC is the optimal *policy mix* between taxing carbon emissions and subsidizing new technologies due to spillover effects, see, e.g., the discussion in Schneider and Goulder (1997). If there are no market failures apart from the externalities connected to pollution, the cost-minimizing policy is to use carbon taxes alone as they directly target the market imperfection. Using technology subsidies as the only policy instrument will give higher costs of reaching the emissions targets, as these do not directly change the prices of carbon-based fuels. But if there are two imperfections, pollution and a technology spillover, the theory of policy goals and measures (Johansen, 1965) shows that the optimal policy is to use both carbon taxes and subsidies. However, in an earlier paper (Kverndokk et al., 2004a), we found that