Economic Modelling xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Economic Modelling

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

Optimal combination of innovation and environmental policies under technology licensing

Keisuke Hattori

Faculty of Economics, Osaka University of Economics, 2-2-8 Osumi, Higashiyodogawa-ku, Osaka 533-8533, Japan

ARTICLE INFO

JEL classification:
Q58
Q55
Q53
L13
L51

Keywords:
Emission taxes
R & D
Environmental damages
Clean technology
Licensing

ABSTRACT

Under what conditions will a carbon tax encourage environmental innovation? Can a regulator design an optimal environmental policy to reduce emissions and to promote clean technologies? This paper studies optimal environmental policy in the situation where a monopoly innovator develops and licenses clean production technologies to downstream polluting firms. We find that (i) a higher emission tax will encourage innovation when the burden of the tax payment in the polluters' costs and/or the price-elasticity of the demand for polluting goods are small, (ii) the innovation-inducing effects of emission tax are inversely related to the emission-reduction (Pigouvian) effects of the tax, and (iii) the social optimum can be achieved by the mix of tax and subsidy. We also show that if the policy instrument is limited to the tax, the second-best tax rate would lie between the marginal damage and the first-best rate. By performing numerical simulations, we also demonstrate that the optimal mix of the emission tax and R & D subsidy can have "double dividend" benefits.

1. Introduction

As an effective countermeasure against long-term environmental problems such as global warming, policymakers have become increasingly concerned with implementing technology policies to promote environmental innovations in addition to conventional regulation policies such as emission taxes, standards, and tradable permits to control pollution. As indicated by Kneese and Schultz (1975), the effect of public policies on the development and spread of new technologies may be among the most important determinants of success or failure in environmental protection. However, designing the optimal combination of the technology and regulation policies may be a difficult task because there is a bidirectional relationship between the two policies: regulation policies affect environmental innovations as well as the level of pollution, and technology-promotion policies affect the level of pollution as well as environmental innovations.

The intellectual property rights system, including the patent system, also plays an important role in encouraging efforts to develop clean technology. Recently, in several developed countries, governments have tried to encourage patent applications in clean technology. For example, the United States Patent and Trademark Office (USPTO) expanded the Green Technology Pilot Program to promote the development of green technologies in 2010.[1] In the UK, the Patent Office implemented a Green Channel for patent applications in 2016 that enabled applicants to request accelerated processing of their application if the invention had an environmental benefit.[2] According to a study by UNEP et al. (2010), patenting rates (patent applications and granted patents) in selected clean energy technologies have increased at roughly 20 percent per annum since 1997, when the Kyoto Protocol was adopted. In addition, there has been a substantial concentration of environmental patents in Germany, Japan, and the USA, and 95–98% of industrial air and water pollution control technology has originated from machinery suppliers that are not engaged in polluting activities (Lanjouw and Mody, 1996). Although patents encourage environmental innovations, they give an innovator monopoly power and the ability to charge prices higher than their cost. Thus, governments may decide to assist in the diffusion and adoption of clean technologies.

In order to analyze the optimal design for a combination of regulation and technology policies, we construct a model of endogenous and monopolistic environmental innovations with perfect or imperfect competition in a polluting goods market. In line with the aforementioned trend on increased patenting, we assume that environmental innovations are made and patented by an upstream monopolist supplier who can license the clean production technologies to downstream polluting firms by charging appropriate royalties. Our model applies to the development of air and water pollution control

E-mail address: hattori@osaka-ue.ac.jp.

[1] For this program, see http://www.uspto.gov/about-us/news-updates/uspto-expands-green-technology-pilot-program-more-inventions.

[2] For information on the Green Channel for patent applications, see https://www.gov.uk/guidance/patents-accelerated-processing.

http://dx.doi.org/10.1016/j.econmod.2017.04.024
Received 9 August 2016; Received in revised form 4 March 2017; Accepted 29 April 2017
0264-9993/

Please cite this article as: Hattori, K., Economic Modelling (2017), http://dx.doi.org/10.1016/j.econmod.2017.04.024

technology and its diffusion, based on the empirical result of Lanjouw and Mody (1996) described above. Given this monopoly structure of the innovation sector, an emission tax alone will not provide sufficient incentives to develop and diffuse technologies. Thus, regulators should employ two policy instruments simultaneously: impose emission taxes to internalize environmental externalities, and provide R & D subsidies for the innovator to mitigate the underprovision of clean technology resulting from monopolistic innovations.

Within the above framework, we first show that introducing emission taxes encourages innovation and diffusion of environmentally clean technologies if the demand for polluting goods is less elastic and/or the tax burden on polluting firms is smaller. The result is interesting because a Pigouvian emission tax is more effective when the demand for polluting goods is more price elastic. In other words, the smaller the tax's Pigouvian effect in reducing emissions, the larger is its indirect effect in spurring innovation and diffusing environmentally clean technologies.

Second, we derive the first-best policy schemes for assuring a socially optimal allocation. The first-best policy combination of an emission tax and an R & D subsidy can completely remove two types of inefficiencies: the overproduction of polluting goods and the underprovision of clean technologies. We find that the optimal tax rate is smaller than the ex-ante Pigouvian levels ignoring innovation, and that the optimal subsidy rate just equals the rate of improvement of emissions technologies through innovative investment. We also investigate the second-best case where the policy instrument is limited to emission taxes, and we compare its equilibrium to the first-best case. It is shown that, in a general case, the second-best tax lies between the optimal and the ex-ante Pigouvian tax rate. Because the second-best policy does not solve the inefficiency arising from the underprovision of new technology, the regulator must levy taxes above the optimal level to increase the innovator's incentives for R & D investment.

Third, by numerical simulations, we investigate the properties of the first-best and second-best policies and consider whether the optimal mix of an emission tax and an R & D subsidy has “double dividend” properties (i.e., whether the distortions caused by environmental externalities and monopolistic provision of clean technologies are completely corrected by appropriating tax revenues for the R & D subsidy payment, with some amount left over to reduce distortions elsewhere in the economy). We find that the double dividend properties are more likely to hold true when the size of the market for polluting goods, marginal damages, and R & D efficiencies are smaller.

We also provide three extensions of our basic model. First, we consider an oligopolistic market for polluting goods. Also in case of an imperfectly competitive goods market, introducing emission taxes encourages innovation and diffusion of environmentally clean technologies if the demand for polluting goods is less elastic and/or the tax burden on firms is smaller. In addition, efficient allocation can be achieved by the appropriate policy combination of an emission tax and a subsidy for R & D unless the degree of competition in the product market is too low. Our second extension considers adoption subsidies as a technology policy instrument in place of R & D subsidies. We show that the optimal policy combination of an emission tax and an adoption subsidy offers exactly the same production and innovation incentives for polluting firms and for an innovating monopolist as does the policy combination of an emission tax and an R & D subsidy. Our third extension considers technology spillovers. As the degree of technology spillovers increase, equilibrium royalties and innovator's incentives to engage in environmental R & D decrease. Therefore, to encourage R & D, the regulator should set higher taxes on emissions and higher subsidies on R & D than would be the case without technology spillovers.

This study relates to the literature on the effects of different environmental policies on technological innovations in a perfectly competitive market for polluting goods (Downing and White, 1986; Milliman and Prince, 1989; Denicolò, 1999; Fischer et al., 2003; Fischer and Newell, 2008). This series of studies generally assumes that the market for polluting goods is perfectly competitive and that government cannot simultaneously employ more than one policy instrument. Our model is largely based on the model developed by Denicolò (1999), who compares the effects of emission taxes and pollution permits on incentives for an upstream monopolistic R & D firm to invest in R & D. We consider emission taxes as regulation policies and subsidies for environmental R & D as technology policies under both perfect and imperfect competition in the polluting goods market, whereas Denicolò (1999) considers only regulation policy under a perfectly competitive polluting goods market. It seems to be obvious that two policy options (emission tax and R & D subsidy) can internalize the two externalities (positive externality on R & D and negative externality on emissions). However, considering the policy combination is important for the following two reasons. First, the analysis enable us to understand the nature of the first-best policies: (i) the optimal tax rate is smaller than both the ex-ante Pigouvian levels ignoring innovation and the second-best tax rate, and (ii) the optimal subsidy rate just equals the rate of improvement of emissions technologies through innovative investment. Second, we also consider the case of an imperfect competition in the downstream market, in which there are three distortions or externalities (positive externality on R & D, negative externality on emissions, and underproduction of the final goods). Even in such a case, the first-best allocation can be achieved by policy combination of emission tax and R & D subsidy.[3]

This study also relates to the theoretical studies that explicitly consider an industry of abatement goods and services, a so-called “eco-industry” (David and Sinclair-Desgagné, 2005, 2010; Requate, 2005b; Canton et al., 2008; Perino, 2010; David et al., 2011). David and Sinclair-Desgagné (2005) investigate an imperfectly competitive eco-industry for abatement goods and find that the second-best pollution tax should be higher than in the case where there is no market power in the eco-industry. In addition, Canton et al. (2008) consider imperfect competition both at the level of an upstream eco-industry and that of a downstream polluting goods industry. They find that the optimal tax depends on the relative degree of market imperfection existing between the upstream and downstream industries. The main difference between these studies and ours is the type of goods or technologies provided by the eco-industry. Specifically, these studies consider an eco-industry that provides abatement goods and services such as end-of-pipe abatement technologies. In contrast, we consider an eco-industry that provides cleaner production technologies that reduce unit emission coefficients for the downstream products. The difference plays a crucial role in characterizing the optimal policy. The other difference is that Canton et al. (2008) focus on the nature of the optimal tax rate while this study investigates not only the nature of the second-best tax but also the fist-best policy combination of tax and R & D (or adoption) subsidy, which enables us to answer the question of whether the introduction of the subsidy raises or lowers the optimal level of emission tax and whether the first-best policies can be implemented with budget surplus. In addition, the environmental goods (or technologies) in Canton et al. (2008) are considered to be general or popularized ones in the sense that many upstream oligopolists can provide them. In contrast, the technologies developed by a monopolist supplier in this paper are patented by patent laws, and therefore the monopolist can fully appropriate

[3] Constructing a two-sector (emitting and non-emitting) perfectly competitive model with three market failures (emissions, R & D spillovers, and learning spillovers), Fischer and Newell (2008) assess six different environmental and technology policies for reducing carbon dioxide emissions and promoting innovation of renewable energy. They find that an optimal combination of an emission price (tax) and subsidies for technology R & D can reduce emissions at a significantly lower cost than any single policy alone.