Ecological Economics 106 (2014) 112–123

Contents lists available at ScienceDirect

Ecological Economics

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

The impact of environmental policy instruments on innovation: A review of energy and automotive industry studies

Anna Bergek *, Christian Berggren, KITE Research Group

Department of Management and Engineering, Linköping University, SE-58183 Linköping, Sweden

ARTICLE INFO

Article history:
Received 19 December 2013
Received in revised form 24 May 2014
Accepted 21 July 2014
Available online 11 August 2014

Keywords:
Environmental policy
Innovation
Policy instruments

ABSTRACT

Various types of policy instruments have been implemented to reduce local and global emissions, but the impact on innovation of different instruments has received less attention. This paper reviews empirical studies of the innovation impact of four main types of policy instruments in two high-emitting sectors. The conclusions are threefold. (1) Policy plays a key role for the development and diffusion of environmental innovation in the studied sectors. (2) Different types of instruments promote different types of innovations: general economic instruments has primarily encouraged incremental innovation, general regulatory instruments has enforced improvements based on modular innovation, and technology-specific instruments appears to have been needed to support the development and deployment of radically new technologies. (3) All types of policy instruments face challenges in design and implementation: understanding the selection impact of the chosen instruments, implementing increasing stringency levels, committing to an appropriate scale, and safeguarding policy stability.

1. Introduction

Government policies, from regulatory standards to economic incentives, are vital for innovations not directly related to customer benefits, such as various types of emissions reduction. Since the 1960s, authorities in the OECD-countries and emerging economies have sought ways to encourage technological development to reduce pollution from production plants and mobile sources. More recently, global greenhouse emissions have come into focus, especially for high-emitting sectors, such as transport and energy generation. A variety of instruments have been applied, from technology-forcing standards or market incentives for specific technologies, to general economic instruments, such as CO_2 taxes and emission allowance trading systems.

The primary goal of environmental policies is to reduce polluting emissions. In this respect, it is often argued that general economic instruments, such as taxes, are more efficient in inducing adoption of emission-reducing technologies than regulatory, "command-and-control" (CAC-) measures,[1] such as emissions regulation for specific products or plants (Bergquist et al., 2013; Jaffe et al., 2002). The core argument is that with general, market-conforming instruments, relevant actors will invest where the cost of pollution abatement is lowest, thus maintaining economic efficiency, whereas subsidies of specific technologies or industries may lead to lock-in effects, as the subsidies of one technology which once seemed promising crowd out other more potent technologies not envisaged at the time of the decision (cf. Jaffe et al., 2005; OECD, 2005).[2]

The focus of this paper is, however, the "side-effects" of environmental policy instruments in terms of their impact on innovation, i.e. the development, market introduction and early diffusion of new products and processes rather than the adoption of already commercially available technologies. Such effects have received less attention in the literature and the conclusions so far are partially conflicting. One the one hand, studies based on microeconomic modeling argue that "instruments which provide incentives through the price mechanism, by and large, perform better than command and control policies" (Requate, 2005: 193); one important reason for this is that with a standard firms lack incentives to perform beyond the pre-determined level, while economic instruments such as pollution taxes induce firms to reduce pollution beyond that standard.[3] On the other hand, empirical comparisons of

* Corresponding author. Tel.: +46 13 282573; fax: +46 13 281101.
E-mail addresses: anna.bergek@liu.se (A. Bergek), christian.berggren@liu.se (C. Berggren).

[1] The juxtaposition of "market-based instruments" with the somewhat derogative term "command and control" measures can be misleading. The negative externality represented by polluting emissions is not internalized by the market just because a tax or trading system is introduced. On the contrary, such instruments, e.g. the European emissions trading system, rely on administrative measurement, reporting and control of actual emissions for their functioning. A proper terminology, analogous with "command and control" would refer to "tax and control" or "trade and control".

[2] Many economists also point out that there can be other obstacles for environmentally benign technologies to develop and diffuse. For example, positive externalities tend to make investments lower than socially desirable, which implies that various other policy interventions, e.g. R&D subsidies and tax credits, might be needed to support technology development and adoption (Fischer et al., 2012; Jaffe et al., 2002). The effects of such technology and innovation policies are not studied in this paper.

[3] This of course presumes that the cost of further pollution reduction by investing in new equipment, e.g., is less than the cost of the avoided tax.

http://dx.doi.org/10.1016/j.ecolecon.2014.07.016
0921-8009/

the innovation impact of various instruments have demonstrated that direct regulation "could imply a greater spur to technology adoption and innovation than market-based instruments" and that "… there appears to be little evidence of one policy instrument being superior compared to others in promoting environmental compliance and innovation" (Bergquist et al., 2013: 7–8).

Existing studies of the innovation impact of policies for environmental innovation tend to focus on one or a few instruments or specific cases of pollution. In a recent review of empirical studies of environmental policy, Kemp and Pontoglio (2011) concluded that the context in which policy instruments are applied is important for their outcomes. Although many contextual factors might influence innovation, several of these can be captured under the umbrella term of 'sector'. Sectors differ with regard to general framework conditions for innovation, such as infrastructural requirements, capital intensities, technological linkages, performance parameters, as well as with regard to the resulting patterns of technical change (cf. Malerba, 2002; Pavitt, 1984). This implies that an analysis comparing effects of various instruments in different sectors would make a fruitful complement to the many country-specific studies of particular pollution reduction cases (for a recent overview, see Bergquist et al. (2013)) and may provide important input for more informed decision-making and policy debates.[4]

Against this background, the purpose of this paper is to present a review of empirical studies of the innovation effects of four main types of policy instruments in two high-emitting sectors: the automotive sector and the energy sector. By such a comparison, we can arrive at a richer understanding of different types of policies in terms of their impact, applicability and limits, but we have no ambition to draw normative conclusions with regard to whether specific policy instruments should be used or not. That depends on, among other things, what the goal of a specific environmental policy intervention is in terms of whether innovation is at all asked for and, in that case, what type of innovation is wanted.

The paper is outlined as follows. In Section 2, we present a framework for classifying (environmental) policy instruments and discussing their impact on innovation, which distinguishes between four types of policy instruments and four types of innovation. In Section 3, we discuss research design, including case selection and how we identified the studies that are included in the review. In Section 4, we review the identified empirical studies and synthesize their findings with regard to the innovation impact of different types of environmental policy instruments. Section 5 contains our conclusions, a discussion of further relevant observations and some suggestions for future research.

2. A Framework for Policy and Innovation Classification

The aim of this paper is to scrutinize available empirical evidence of the innovation impact of different types of environmental policy instruments, by means of a two-sector comparative approach. We structure the review using a framework that distinguishes four types of policy instruments and discuss their impact on four types of innovation. It should be noted that this paper is limited to technological product and process innovations, i.e. organizational innovations are not included.

2.1. Policy Instrument Typology

Two main distinctions are made with regard to instrument type. First, in line with previous literature on environmental policy, we distinguish between economic and regulatory (prescriptive) instruments.[5] Second, we distinguish between general and technology-specific instruments. In some cases there may be a gray zone between what could be seen as "general" and "specific", but the distinction has been widely used in the literature where the relative pros and cons of general vs. technology-specific instruments is an important issue (cf., e.g., Sandén and Azar, 2005).

Some recent literature argues that the innovation impact of policy instruments is mediated — or even determined — by design features rather than by instrument types (cf, e.g., Bergquist et al., 2013; Brouillat and Oltra, 2012; Kemp and Pontoglio, 2011). In particular, several studies (cf. Johnstone et al., 2010a; Rogge et al., 2011; Yin and Powers, 2010) discuss the influence of stringency (how difficult or expensive it is for market actors to comply) and predictability (how certain and foreseeable the policy signal is). However, the literature has also recognized the difficulty of measuring and comparing such features across countries and sectors (Johnstone et al., 2010a). Considering this, we do not include design features in our comparative analysis. We will return to this issue in the Conclusions and discussion section.

2.1.1. Economic vs. Regulatory Policy Instruments

Economic instruments aim at providing actors with incentives to adopt low-emission technologies: actors who invest in sustainable solutions should receive an economic compensation corresponding to the avoided social cost of pollution, whereas actors who invest in a polluting technology should be economically punished. Firms are then expected to undertake pollution control efforts in their own interest (Stavins, 2003). Regulatory instruments (often referred to as direct regulation) aim at controlling the actions of firms, for example via technological standards (i.e. prescription of a certain method, equipment or technology), emission standards (an absolute upper emission level), and performance standards, such as a cap on emissions per unit of output. Other types of regulatory instruments include bans or prescribed use of certain solutions and permits for building and operation of plants. Whereas some of these regulations are compulsory, others are optional, i.e. firms can choose whether or not to comply, but non-compliance may come with a penalty or other negative consequences.

According to Requate (2005) instruments that work through the price mechanism offer incentives for private actors to develop improved technologies and make it attractive for firms to clean up more than mandated if feasible technologies are available (cf. also Bergquist et al., 2013; Jaffe et al., 2002; Stavins, 2003). It can, however, be politically difficult to, for example, set high enough carbon taxes to induce the required innovation efforts (Fischer et al., 2012). Moreover, the impact of price incentives on innovation can be limited in markets where buyers only carry a fraction of the actual cost of use. One example is the construction sector where owners of multi-tenant houses seldom are the actual end-users and do not carry the cost of use, e.g. the penalty of poor insulation (Noailly, 2012). Similar problems exist in the automotive sector, where the life-time value of a more efficient product exceeds the perceived value for the first customer who only includes the savings during the first 2–3 years at the time of their buying decisions (Greene, 2010).

With regard to regulatory instruments, it has been shown that performance and technology standards can pressure firms to develop products and processes to meet the requirements (Grubb and Ulph, 2002), as long as standards cannot be achieved with current technologies (Jaffe et al., 2002; Popp et al., 2009). It can, however, be costly for firms to develop technologies to meet regulatory standards (Lee et al., 2010), and this, it is argued, might reduce the overall means available for innovation (cf. Chappin et al., 2009; Jaffe et al., 2002).

[4] Comparisons of countries may provide general insights on regulatory regimes, for example comparisons of the US regime of central control with the more flexible and collaborative approaches pursued in European countries (Löfstedt and Vogel, 2001), but their contextuality makes them less suited to analyze the impact of specific instrument types.

[5] Considering that economic instruments are also regulated, a more correct term would be "direct regulatory instruments" (cf. Goulder and Parry, 2008). For reasons of simplicity, we nevertheless use the shorter term "regulatory instrument" instead.