Technological Forecasting & Social Change 111 (2016) 222–234

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

Fuel prices and the invention crowding out effect: Releasing the automotive industry from its dependence on fossil fuel

Nicolò Barbieri

Department of Economics and Management, University of Ferrara, Via Voltapaletto, 11, 44121, Ferrara, Italy

ARTICLE INFO

Article history:
Received 22 May 2015
Received in revised form 1 July 2016
Accepted 3 July 2016
Available online 5 August 2016

Keywords:
Environmental technologies
Self-Organising Maps
Crowding out
Fuel prices
Patent data

ABSTRACT

The paper aims to shed some light on the impact of fuel prices and technological relatedness on green and non-green patenting dynamics and lock in to fossil fuel technologies. Specifically, we investigate whether green technology efforts come at the expense of other environmental or non-environmental invention activity. To do so, we employ Self-Organising Maps (SOMs) to detect the main technological domains exploited by the automotive industry during 1982–2008, using Triadic Patent Families (TPF) to proxy for the technological efforts in each technology field.

The paper adds to the literature by examining explicitly whether fuel prices (used as a proxy for carbon tax) and technological proximity foster the substitution of non-green patents by green ones. In addition, we provide a novel contribution by testing whether these determinants impact on the competition among low-emitting vehicles.

Our findings suggest that higher, tax-inclusive fuel prices are effective at redirecting patenting activity from non-green to green technology fields. Moreover, we observe that tax-inclusive fuel prices also induce a shift in patenting activity when we perform the analysis solely on green technology fields. Although this might result in potential lock-in to sub-optimal substituting technologies, our findings suggest that competition in the domain of environmental technology is focused mainly on 'greening' conventional cars and developing low-emission vehicles.

1. Introduction

The impact of prices and policies on the development and adoption of clean technologies has been investigated extensively over the last decades. Although this body of research provides evidence that prices and policies affect environmental technological change (surveyed in Popp et al., 2010 and Barbieri et al., 2016), few studies focus on whether they affect the competition between clean and dirty inventive activities. Indeed, although alternative technological trajectories might improve environmental performance, evolutionary economists emphasise that the process of technology selection is path dependent, not predictable ex ante and irreversible; thus, the market may select sub-optimal technologies based on the increasing returns to adoption (Arthur, 1989; Bruckner et al., 1996; Frenken et al., 2004). This conservatism in market selection, on the one hand, has a negative effect on the probability that alternative technologies will be adopted ('self-reinforcement') and, on the other, allows producers to take advantage of economies of scale and R&D investments (David, 1985).[1] In addition to path dependence in technology adoption, Acemoglu et al. (2012) state that the type of innovation produced follows a path-dependent process, which provides incentives for firms that have previously developed dirty technologies to continue to develop them in the future.

It should be noted also that the evolutionary process at the basis of technological change highlights that the success of technological advancement cannot be determined ex ante (Nelson and Winter, 1982). This is due mainly to the uncertainty surrounding the design and planning processes. For example, successful technological advances are the result of a process in which, at any time, a range of technological opportunities is undertaken and proposed to the selection environment (Gelijns et al., 2001). Therefore, there is competition among innovations, and the prevailing technology is determined by ex post selection (Gelijns et al., 2001).

Furthermore, in the case examined in the present paper, that is, the automotive industry, we find that technological uncertainty also affects the development of low-emissions vehicles. One source of uncertainty is linked to the capability of alternative cars to substitute for conventional vehicle designs and another is related mainly to competition *between* alternative vehicles since, in the current climate, it is unclear which alternative option should be preferred from both an economic and environmental perspective (Frenken et al., 2004).

E-mail addresses: brbncl@unife.it, n.barbieri@unibo.it.

[1] In David (1985), the author ascribes the lock in to QWERTY to technical interrelatedness, economies of scale and the quasi-irreversibility of investment.

http://dx.doi.org/10.1016/j.techfore.2016.07.002

Against this complex background, where uncertainty, path-dependence and competition prevail, several authors highlight that policy intervention is one of the main factors that might allow socio-technical lock-ins to be reduced (Faber and Frenken, 2009; Rennings et al., 2013) and, specifically, for lock in to Internal Combustion Engine Vehicles (ICEV) be avoided (Cowan and Hultén, 1996).[2] Recently, several authors have highlighted the role of environmental policies in inducing development of environmentally-sound technologies (Popp et al., 2010; Bergek et al., 2014). However, although it has been shown that environmental policies lead to increasing innovative performances and market competitiveness (Porter and Van der Linde, 1995), the production of eco-innovations can have secondary effects such as environmental rebound, the green paradox and crowding out (van den Bergh, 2013). Indeed, environmental policies can lead to higher opportunity costs derived from real resources (financial and human) requirements for the development and adoption of alternative technologies to comply with policy objectives (Jaffe et al., 2002). They can trigger innovation in green technology domains which may drive inventive activity from non-environmentally friendly to green innovations, becoming a potential source of innovation crowding out.

The present paper investigates the role played by fuel prices (our proxy for a carbon tax) on technology dynamics, in a sample of automotive firms, i.e. we analyse the effectiveness of fuel prices for breaking the link with ICEV technologies. In this context, the crowding out effect, generated by higher fuel prices, may favour this objective; although crowding out of any type of innovation reduces the social benefits[3] and decreases competition, it might help to delink the automotive industry from its dependence on fossil fuel, that is, it might work to reduce innovation activity in ICEVs in favour of Low-Emissions Vehicles (LEVs).

With a few exceptions which are discussed below, this topic has been mostly unexplored, and very little debate has been about policy-driven crowding out effects and, especially, 'what' is being crowded out. If improvements in technologies with negative environmental effects are crowded out to favour advances in green technologies, the costs to society of this crowding out could be reduced (Popp, 2005) or, in the case that this crowding out affects other environmental technology efforts, increased. Therefore, we test whether invention activity in the area of environmental technologies comes at the expense of other green inventions.

The paper is structured as follows: Section 2 discusses the related literature; Section 3 explores the main features of the automotive technological system, presents the data and identifies the main technological trajectories using Self-Organising Maps (SOMs). Section 4 describes the building of the main variables and the empirical model and Section 5 discusses the results. Section 6 concludes the paper.

2. Literature review

In a recent review of studies investigating eco-innovation from an evolutionary perspective, Cecere et al. (2014) emphasise that technological, social, organisational and institutional lock-ins affect environmental innovation development and adoption. This suggests that firm-level strategies, technological niches and regulation are the key to overcoming path dependence on the dominant technological designs. In particular, there is one literature stream that provides evidence of the effectiveness of environmental policy for boosting green technologies (surveyed in Popp et al., 2010) and sheds light on its potential to unlock technological systems. Several studies of environmental regulation assess whether environmental policy fosters technological change towards a more sustainable path. However, this body of work on the policy-induced development of environmental technologies does not provide direct insights into the potential competition between non-green and green inventions. To understand the overall effect of green policy on the economic system, it is necessary to take account of potential secondary consequences of policy implementation in order to appreciate their overall impact, beyond the development of new green technological efforts. Indeed, environmental inventions may come at the expense of non-green innovations or may become complements in firms' innovation portfolios. However, analysis of the crowding out effect has been hampered by the difficulties involved in addressing this issue empirically. It is difficult also, even ex post, to identify whether a change of direction in innovation activity is due to policy intervention or research opportunities and firm strategies.

A seminal work that discusses the presence of a crowding out effect is Gray and Shadbegian (1998). The authors examine the impact of environmental regulation stringency in the pulp and paper industry. In their study, crowding out affects decisions about investment in pollution abatement, and productive (non-environmental) capital investments. Their results suggest that investment in pollution abatement crowds out other productive (non-abatement) investments within a plant.

Marin (2014) uses a dataset of Italian manufacturing firms and provides evidence (at least in the short run) that environmental innovation comes at the expense of non-environmental innovation. This possible crowding out is driven mainly by the lower returns which distinguish eco-innovation from other investments, coupled with the constrained financial resources devoted to R&D activities.

When firms are not financially constrained, a decrease in non-environmental innovations caused by an increase in green innovation, does not always imply that the crowding out effect reduces the social and private benefits. Popp and Newell (2012) investigate whether the increase in environmental R&D spending leads to lower levels of R&D investment in other fields. First, the authors find no evidence of crowding out across sectors, 'mitigating the concern that new energy R&D programs will draw resources away from other innovative sectors of the economy' (Popp and Newell, 2012, p. 990). Second, using patent data to proxy for R&D expenditure, they examine whether this hypothesis holds within sectors and find that an increase in alternative energy patents leads to a decrease in other patents. However, the absence of financial constraints in the firms studied might suggest that the crowding out effect is driven by changes in market opportunities. This second result underlines the positive environmental effect of crowding out, which seems to induce development of green technologies at the expense of dirty ones, which helps to satisfy environmental policy objectives.

More evidence of an R&D offsetting comes from Kneller and Manderson (2012). Their results highlight that an increase in environmental compliance costs boosts environmental innovation, although the effect of environmental expenditures does not have a positive impact on the total amount of R&D investment, suggesting that environmental R&D crowds out non-environmental R&D.[4]

As a result mainly of the research questions addressed, most of these studies do not directly examine the role of environmental policies in this framework. An exception is Hottenrott and Rexhäuser (2013), which employs survey-based data to identify which firms introduce environmental technologies as a consequence of policy compliance behaviour. Their study suggests that, while there is evidence that environmental innovation crowds out firms' in-house R&D expenditure, this does not seem to influence the number of existing R&D projects, their outcome or the amount of investment in fixed assets (both innovation-related and other). In addition, the authors suggest that firms prefer to scale down long-term oriented R&D activities which are not connected directly to production and which provide relatively uncertain returns. A recent work by Noailly and Smeets (2015) on directed technical change,

[2] In addition to regulation, the authors identify other factors such as problems in existing technology, radical technologies, differences in taste, niche markets and scientific achievements (Cowan and Hultén, 1996).

[3] The social returns from research are greater than the private returns to firms (Jaffe, 1986; Mansfield et al., 1977; Pakes, 1985).

[4] The authors highlight the lack of evidence that environmental capital crowds out non-environmental capital.