Research Policy 42 (2013) 15–22

Contents lists available at SciVerse ScienceDirect

Research Policy

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

Induced innovation and technology trajectory: Evidence from smoking cessation products

Seth H. Werfel, Adam B. Jaffe*

Brandeis University, 415 South Street, Waltham, MA 02453, United States

ARTICLE INFO

Article history:
Received 8 November 2010
Received in revised form 7 March 2012
Accepted 24 April 2012
Available online 21 May 2012

JEL classification:
O31
O38
H23
I18

Keywords:
Induced innovation
Technology trajectory
Smoking cessation products
Cigarette taxes

ABSTRACT

Economic theory predicts that policies that discourage the consumption of a particular good will induce innovation in a socially desirable substitute. However, the literature on technology trajectories emphasizes the possibility of innovation waves associated with the identification of new dominant designs. We incorporate both of these possibilities in a model of the invention of new smoking cessation products, based on a new dataset of patents on such products from 1951 to 2004. We find that an increase in cigarette tax levels had no discernible impact on the industry-wide rate of invention in smoking cessation products. However, we do find evidence consistent with the emergence of dominant designs having substantial positive innovation effects. We estimate that the introduction of the nicotine gum and patch increased the overall rate of patenting activity in smoking cessation products by 60–75%, subject to a 10% rate of decay. Finally, we show that these products had greater effects on the patenting of corporations than individual inventors.

1. Introduction

Cigarette smoking is the leading preventable cause of death in the United States. According to the Center for Disease Control (CDC), smoking is responsible for approximately one in five deaths annually, or about 443,000 deaths per year. In the last several decades, technology has provided effective and affordable ways for addicted smokers to "break the habit." Smoking cessation products, mainly comprised of nicotine replacement therapies, have been at least partially responsible for a decrease in smoking rates from more than 42% to less than 20% of American adults over the past forty years.

More generally, there are numerous public policy problems for which new technology is important. The most prominent of these is global climate change, where it seems clear that significant damage will be avoided at reasonable economic cost only if new low-carbon or carbon-free technologies can be deployed at massive scale. There is currently an active debate as to whether and how public policy might foster the desired innovation. The literature on induced innovation provides an explicit framework to consider the mechanisms by which specific policies might increase the rate of innovation in particular areas, but there is relatively little empirical work documenting the significance of different factors in different contexts. We consider the public health problem of smoking and the development of cessation products as a case study that may inform the larger question of how to induce the innovation of socially desirable technologies. We recognize that technological and market options vary across industries, and therefore offer these findings only as elements of a larger research agenda on the sources of technological change, not as bearing in any direct way on policy choices in other contexts.

The body of this paper will be organized as follows. Section 2 explores public policy as a source for induced innovation. Section 3 introduces two hypotheses about the rate of innovation for smoking cessation products from the economics literature on innovation and technology trajectories. Section 4 describes the quantitative and qualitative data used in this empirical study. Section 5 outlines our model specification and estimation strategy, while Section 6 discusses the results of our empirical analysis. Finally, Section 7 summarizes our argument and draws conclusions about the causal link between the rules of the market and the marketplace of ideas.

2. Public policy and induced innovation

Public policies are designed to achieve multiple social goals. We can identify three main types of policy aims that might alter

* Corresponding author.
E-mail addresses: swerfel@brandeis.edu (S.H. Werfel), ajaffe@brandeis.edu (A.B. Jaffe).

0048-7333/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.respol.2012.04.013

the course of technological change. The first type of policy aims to change the actual innovation system, but remains neutral with respect to the specific types of innovation that it might encourage. Examples of this type of policy range from changes in the patent system to R&D subsidies and tax credits, among others (Jaffe, 2000). In addition, we can pinpoint specific pieces of legislation that have had various effects on the rate of innovation, such as the Bayh-Dole Act of 1980 that gave research universities and small businesses the right to patent inventions that resulted from government funding (Mowery et al., 2004), the establishment of the Court of Appeals of the Federal Circuit by Congress in 1982 that presides over patenting activity (Kortum and Lerner, 1999), and a 1991 law that increased patent application fees and made the United States Patent and Trademark Office (USPTO) an almost fully user-fee funded agency (Sanyal, 2003).

A second type of public policy focuses on achieving a certain social goal by encouraging a specific type of innovation. For example, the Orphan Drug Act (ODA) of 1983 was designed to incentivize the development of pharmaceutical products used to treat rare diseases in small, relatively unprofitable consumer markets. Yin (2008, 2009) found that the legislation mostly induced innovation within ODA-qualifying subdivisions for non-rare diseases, which deviated from the primary goals of the legislation. Furthermore, the author estimated that 10% of the induced innovation might have occurred in the absence of the legislation. In either case, the study showed that firms did respond to incentives; however, the resulting inventive output was only tangentially related to the social goal of the legislation.

The third category of public policy focuses on achieving some social goal other than innovation, but either intentionally or unintentionally may induce innovative activity among other responses. In the energy and environment sector, Jaffe and Palmer (1997) concluded that environmental compliance standards increased R&D spending at the firm level, but did not necessarily induce inventive output in the form of successful patent applications. In a related study, Popp (2003) found that the Clean Air Act of 1990, which instituted a market for sulfur dioxide (SO_2) permits, enhanced the efficiency of "scrubbers," or flue gas desulfurization units. Most recently, Johnstone et al. (2010) found that different types of environmental policy instruments had a significant positive effect on patent counts for new sources of renewable energy. Similarly, in the health sector, Finkelstein (2004) showed that policies designed to increase the usage of preexisting vaccines induced a 2.5-fold increase in clinical trials for new vaccines. In the most ambitious project of this nature, Acemoglu et al. (2006) demonstrated that the introduction of Medicare did not induce pharmaceutical innovation: an increase in drug usage by the elderly did not correspond with an increase in FDA drug approvals for treatments for diseases that affect the elderly. Finally, Acemoglu and Finkelstein (2008) found that the shift from full labor cost to partial cost reimbursement for hospitals under the Medicare Prospective Payment System (PPS) caused substantial increases in capital-labor ratios and a corresponding decrease in labor inputs. This empirical finding supports the induced innovation hypothesis – as the relative price of labor increased, hospitals economized the use of this factor of production. In addition, the authors found that the PPS also encouraged the adoption of a wide range of new medical technologies.

Within this latter category, researchers have tried to determine whether different policy approaches to achieve a given substantive goal (e.g. cleaning up the air) are more or less likely to induce innovative responses. For example, there is both a theoretical and empirical literature on "market-based" policies such as taxes or subsidies versus "command and control" policies such as specific performance standards. Unfortunately, neither theory nor empirics has been conclusive in this debate. In this paper, we do not start from any particular presumption about which policies may have been more effective, but merely analyze the policies that were enacted in a framework that allows for all possible inducement effects.

3. Cigarette taxes and smoking cessation products

In the previous section, we observed that policies that encourage the use of existing products can also promote innovation in related technologies (Finkelstein, 2004). This paper addresses the inverse relationship as its main research question. Do policies that discourage the use of existing technologies induce innovation in socially desirable substitutes? In particular, does an increase in cigarette taxes induce innovation in the market for smoking cessation products? Cigarette taxes were first imposed to generate revenue before there were any concerns about the health effects of cigarette smoking (Chaloupka et al., 2002). However, economists have convincingly demonstrated that an increase in cigarette taxes also leads to a decrease in cigarette consumption given several individual and location fixed effects (Baltagi and Levin, 1986; Flewelling et al., 1992; Peterson et al., 1992; Lewit et al., 1997; Ringel and Evans, 2001; Tauras, 2004, 2006).

The empirically demonstrated effect of cigarette taxes on cigarette consumption operates through several mechanisms, including deterring people (particularly youths) from beginning to smoke, reducing the rate of consumption of people who continue to smoke to some extent, and increasing the rate at which people quit smoking. In terms of the latter pathway, it seems reasonable to investigate whether an increase in the price of cigarettes increases the demand for smoking cessation products, especially given the addictive nature of smoking (Tauras and Chaloupka, 2003; Tauras et al., 2005). Increases in public awareness about the negative health effects of cigarette smoking should have similar effects by the same logic. In this paper, we do not explicitly model or measure the market demand for smoking cessation products. Instead, we empirically investigate whether, in this particular case, exogenous changes in factors potentially affecting the demand for smoking cessation products had a measurable "demand-pull" impact on the rate of invention for these products.[1]

At the same time, we consider the extent to which invention responds to the quality or direction of previous technological change, causing technology to follow specific paradigms or trajectories of evolution (Dosi, 1982; Helfat, 1994). In these models, particular technological developments may spur explosions of innovative activity, rather than gradual change over time. The emergence of a new design paradigm may spur a burst of innovation as multiple firms exploit it. We sometimes see the emergence of a *dominant design* embodying a particular set of product functions or attributes, and a product architecture that delivers those functions (Rosenbloom and Cusumano, 1987; Henderson and Clark, 1990). Eventually, innovation slows down once the market has selected the dominant design and this trough continues until a new and improved design is developed (Abernathy and Utterback, 1978). These observed cycles follow a pattern of differentiation, selection, and imitation, which is similar to the "windows of opportunity" described in the management literature (Anderson and Tushman, 1990; Tyre and Orlikowski, 1994). To capture these ideas, we incorporate variables representing technology-trajectory developments

[1] At some point, policies or other forces that reduce the number of smokers would eliminate the demand for smoking cessation products, since if there are no smokers then nobody needs to quit. Given that the number of smokers worldwide is huge and still growing, we do not think that this ultimate possibility is relevant for our analysis of past experience in the industry.