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The impact of technology-push and demand-pull policies on technical change – Does the locus of policies matter?

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ABSTRACT

How to foster technical change is a highly relevant and intricate question in the arena of policymaking. Various studies have shown that technology-push and demand-pull policies induce innovation. However, there is a lack of work that distinguishes between the loci of policy support when assessing the policy–innovation relationship. We address this gap by shedding light on the question how the innovation effects of domestic and foreign demand-pull and technology-push policies differ. Using solar photovoltaic modules as a research case we conduct a panel analysis on 15 OECD countries over the period 1978 through 2005 with patent data. Three key findings emerged: First, our analyses find no evidence that domestic technology-push policies foster innovative output outside of national borders. Second, both domestic and foreign demand-pull policies trigger innovative output in a country. Third, we detect no indication that market growth induced by domestic demand-pull policies leads to more national innovative output than market growth induced by foreign demand-pull policies. Consequently, demand-pull policies create significant country-level innovation spillovers, which could disincentivize national policymakers to engage in domestic market creation. Based on these findings we discuss the need to establish supranational demand-pull policy schemes in order to address the spillover issue.

1. Introduction

Society is facing serious problems such as climate change and resource depletion. To counter these challenges a "technology revolution" (Galiana and Green, 2009) in the field of clean technologies is required in order to decouple economic growth from adverse environmental impacts. Spurring technical change, i.e., the development and diffusion of new and/or improved technologies, is therefore pivotal. Yet in order to overcome market failures inherent in many environmental issues, policy support is crucial to foster technical change (Del Rio Gonzalez, 2009). This raises the question how public policies should be designed to deliver clean technology innovations (e.g., Mowery et al., 2010). Scholars widely agree that technical change is triggered by the supply side, i.e., progress in science, as well as by the demand-side. This dichotomy of technology-push and demand-pull has also been used to analyze the effect of policy on innovation (Rennings, 2000), and numerous studies have come to the conclusion that both policy types 'induce' innovation (e.g., Taylor et al., 2005).

However, thus far very few empirical studies have considered the locus of policy support when scrutinizing the impact of technology-push and demand-pull policies on innovation. Most scholars have focused on the effect of *domestic* policies while not accounting for a potential impact of *foreign* country-level policies on innovation in a country (e.g., Johnstone et al., 2009). Yet, a good understanding of country-level innovation spillovers – an effect that occurs when domestic innovation is triggered by foreign policies and vice versa – is crucial for policymakers, particularly when they invest public money in domestic policy schemes. Does innovation from domestic policy funding only accrue within the home country or do foreign industries also benefit? For example, in recent years German policymakers have invested several billion EUR annually into creating markets for photovoltaic technology, while the annual German public R&D funding in this field has remained below 50 million EUR. Subsequently, and in light of these large investments maybe not surprisingly, a heated debate has unfolded over whether this policy mix yields sufficient national innovative output and increases industry competitiveness or whether Germany is funding the 'learning curve of the world'.

The very limited number of studies that address the innovation effect of *foreign* policies have yielded inconclusive results. For demand-pull policies, Popp (2006) finds no evidence of country-level innovation spillovers in the case of air pollution control technologies. Opposed to that, Dechezleprêtre and Glachant (2011) investigate wind power and show spillovers from demand-pull policies, but – surprisingly – not from technology-push policies,

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although a positive effect could be expected with the general literature on R&D spillovers (Griliches, 1992).

To contribute to a clarification of these diverging findings, this paper distinguishes between different loci of policy support and addresses the question how the innovation effects of domestic and foreign demand-pull and technology-push policies differ. To do so, we use the case of solar photovoltaic modules and conduct a panel analysis with patent data of 15 OECD countries in the period 1978 through 2005.

The structure of this paper is as follows: In the subsequent section, we present our hypotheses on the innovation effects of different policy measures. In Section 3 we provide details on the research case before we describe our methodology. Section 5 presents the results, which we discuss in Section 6 before we conclude.

2. Policy-induced technical change: review and hypotheses

Two kinds of theories emerged in the 1950s and 1960s to explain technical change: "technology push" and "demand pull" (Dosi, 1982). The technology-push concept assumes a supply-side-driven and mainly linear process from research to development and ultimately to diffusion (Bush, 1945). In response to the advocates of technology-push, Schmookler (1966) formulated the demand-pull hypothesis, postulating that anticipated market demand was a key determinant of technical change by incentivizing research in new directions. The debate around the driving forces of technical change has reached a consensus that a combination of technology-push and demand-pull is necessary as they closely interact (Mowery and Rosenberg, 1979).

It has been widely recognized that for environmental innovations in particular, policy support is an important trigger (Kemp, 1997) for three main reasons. First, as most environmental technologies still require substantial R&D investments until reaching competitiveness, they suffer especially from knowledge spillovers (Rennings, 2000). Second, the uncertainty about future returns of environmental R&D investments is particularly high (Jaffe et al., 2002). Third, negative external effects inherent in most environmental issues put the relative competitiveness of environmental technologies at a disadvantage (e.g., Horbach, 2008). These problems can be addressed with technology-push and demand-pull policies: Technology-push policy is typically enacted as public R&D funding and, as such, can directly mitigate underinvestment in R&D. Demand-pull policies can be devised as market based instruments such as tradable permits, feed-in tariffs or command and control regulation inducing demand through standard setting (Jaffe et al., 2002). As a consequence, demand-pull policies can reduce the uncertainty of R&D investments through the creation of markets and can compensate for competitive disadvantage caused by negative external effects.

In the following sections, we derive two sets of hypotheses focusing on the innovation effects of (I) technology-push policies, and (II) demand-pull policies. For both policy determinants we evaluate how the effects of domestic and foreign policies differ.

2.1. Innovation effects of domestic and foreign technology-push policies

Thus far, a wide set of empirical studies has demonstrated a positive influence of domestic technology-push policies on innovative output. Examples include a study by Watanabe et al. (2000), who econometrically assess the effect of national public R&D funding on innovation in the Japanese PV sector and argue that this funding initiated a "virtuous cycle", creating innovation, price reductions, market growth, and additional industry R&D. Besides solar energy Johnstone et al. (2009) also evaluated the effect of public R&D funding on other renewable energy technologies using patent counts to measure innovative output. For three out of five technologies, their results indicate a positive effect of public R&D funding on innovation. In the field of sulfur dioxide (SO_2) abatement technologies, there are also indications that technology-push policy instruments have a positive impact on innovation (Taylor et al., 2005). Assessing wind energy innovation with a two factor learning curve model, Klaassen et al. (2005) also detect a positive effect of public R&D funding on innovation. These empirical findings are consistent with arguments to be found in the general literature on technical change: Technology-push has a positive effect on innovation as it broadens the scope of search and thus also exploits opportunities beyond existing avenues (Dosi, 1988). Therefore we hypothesize:

H I a. The higher the domestic technology-push policy funding in a technological field, the higher a country's innovative output.

Interestingly, the vast majority of studies exclusively scrutinize the effect of *domestic* technology-push policies on innovation. Only very recently has the impact of foreign technology-push policies on a country's innovative output been analyzed in a study on wind energy. No positive innovation effect of such policies has been found (Dechezleprêtre et al., 2011). It appears to be a sound assumption that governments award technology-push policy funding almost exclusively to domestic innovators in order to support the development of national industries. However, in contrast to these empirical findings, innovators might nevertheless benefit from foreign technology-push policy funding due to knowledge spillovers. It is widely recognized that knowledge spillovers exist on a national as well as an international level (Griliches, 1992; Grossman and Helpman, 1991). Building on this, we expect that the knowledge created through technology-push policies in a certain country will also partly spill over to other countries. Therefore, we postulate a positive innovation effect of foreign technology-push policies and test the following hypothesis:

H I b. The higher the foreign technology-push policy funding in a technological field, the higher a country's innovative output.

Although spillovers exist on an international level, they primarily occur within a country (e.g., Jaffe et al., 1993). In addition, as outlined above, domestic innovators are unlikely to benefit directly from foreign technology-push policy funding. In conclusion, despite a positive effect of growth in foreign technology-push policy funding on innovation in a country, we expect this effect to be weaker than in the case of domestic technology-push policies. We therefore hypothesize:

H I c. The growth in domestic technology-push policy funding triggers more innovative output in a country than the growth in foreign technology-push policy funding.

2.2. Innovation effects of domestic and foreign demand-pull policies

Scholars of environmental economics widely assume that demand-pull policies not only lead to diffusion but also induce innovation (Newell et al., 1999). Also, evolutionary approaches to policy suggest that governments should use demand-pull policies to create niche markets, which protect emerging technologies from competition with established designs (e.g., Kemp et al., 1998; Nill and Kemp, 2009). However, these literature streams mostly do not differentiate between the effect of domestic and foreign demand-pull policies. While various empirical studies find support for the 'inducement effect' of demand-pull policies, they mainly focus on the impact of domestic demand-pull policies on innovation in a country: For example, using patent data Popp (2003)