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Environmental regulation and the cross-border diffusion of new technology: Evidence from automobile patents

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ABSTRACT

We examine the impact of environmental regulation on the international diffusion of new technology through the patent system. We employ a dataset of automobile emission standards between 1992 and 2007 and corresponding data on cross-border patent inflows of technologies developed to comply with these standards. Our analysis, based on a research design of country pair years, shows it is "regulatory distance" between countries rather than absolute regulatory stringency per se that matters for cross-border patent inflows: the flow of compliance technologies rises when regulatory standards in the inventor and the recipient countries become "closer".

1. Introduction

There is widespread agreement that the enhanced cross-border diffusion of environmentally sound technologies (ESTs)[1] is key to addressing environmental problems (WCED, 1987; Popp, 2011; Beyer and Urpelainen, 2013). These flows of technology are particularly significant for developing countries because they are rapidly adding new capacity and, moreover, the vast majority of ESTs are still developed in OECD countries (Dechezleprêtre et al., 2011).

The question of how to accelerate cross-border flows of ESTs has stimulated a debate about the role of government policy. Much of the existing controversy in this area has surrounded intellectual property rights (IPRs) and the degree to which strengthening IPR regimes helps or hinders the international diffusion of new technology (see, for example, Hall and Helmers, 2010; Ockwell et al., 2011). By contrast, the impact of public environmental regulation on cross-border flows of new ESTs has proved less controversial, typically underpinned by a general assumption that tighter domestic environmental regulation automatically increases the cross-border flows of ESTs (Tébar Less and McMillan, 2005; Gallagher, 2006). Indeed, a number of past studies support this assumption, showing a positive relationship between domestic regulatory stringency and inflows of compliance technologies (Lanjouw and Mody, 1996; Popp et al., 2011; Dekker et al., 2012).

However, not all works show that more stringent domestic environmental regulation stimulates the international diffusion of ESTs. For example, Popp (2006) finds that tighter air pollution standards in the power sector in the US did not result in higher levels of compliance technology inflows from Germany and Japan, but only greater local innovative efforts. In addition, empirical studies into the relationship between regulation and cross-border technology flows suffer from various shortcomings. First, they do not use measures which directly capture actual regulatory stringency, with the majority instead relying on proxies such as pollution abatement expenditure (e.g. Lanjouw and Mody, 1996) or ratification of international environmental agreements (e.g. Dekker et al., 2012). Second, existing studies are mainly based on fairly small samples, particularly in terms of the number of recipient countries (e.g. Popp et al., 2011). Third, existing work has almost exclusively focused on environmental process standards, thereby neglecting the potentially crucial role of environmental product standards in the cross-border flow of ESTs.

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[1] ESTs are defined by Agenda 21 as technologies which 'protect the environment, are less polluting, use all resources in a more sustainable manner, recycle more of their wastes and products, and handle residual wastes in a more acceptable manner than the technologies for which they were substitutes.'

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In this paper, we provide new evidence on the role that environmental regulation plays in cross-border flows of compliance-related technologies based on a newly constructed panel data set that combines the level of motor vehicle emissions product standards in 72 countries between 1992 and 2007 with patent filings in corresponding automotive emissions reduction technologies. National emission standards are all expressed in terms of European Union (EU) standards equivalent, making it possible to compare the regulatory level both across countries and across time. We complement these regulatory data with data on non-resident patents protecting technologies that are developed specifically to comply with automotive emissions standards. Data on inventors' country of residence for these patents allow us to measure cross-border technology flows, following an established tradition in the literature (Chan, 2010; Dechezleprêtre et al., 2013; Dekker et al., 2012; Eaton and Kortum, 1999; Lanjouw and Mody, 1996; Perkins and Neumayer, 2011; Popp et al., 2011; Yang and Kuo, 2007). To mitigate the well-known problem that many patent applications relate to technologies of low value, our outcome measure focuses on those patents that, after scrutiny, were actually *granted* by the foreign patent office, as opposed to the more expansive category of all patent *applications*[2]. During our sample period, 183,000 patents in automobile emissions control technologies were granted worldwide to non-residents.

Our main argument and findings can be summarized as follows: what matters for inflows of ESTs is not domestic regulatory stringency as such, but the level of regulation *relative* to potential source[3] countries, or what we call regulatory distance. Indeed, we find strong and robust evidence that countries receive more non-resident patents from source countries whose level of regulation is closer to their own. An increase in regulatory stringency simultaneously raises patent inflows from countries that have a higher regulatory level and decrease patent inflows from countries with lower regulation levels. Once we control for regulatory distance, absolute regulatory stringency in potential destination countries of technology inflows ceases to matter. Therefore the impact of absolute regulatory stringency on the total number of patent inflows is a priori ambiguous and depends on the country's regulatory position relative to that of major inventor countries.

Our paper relates to two strands of existing literature. First, our study draws from, and contributes to, work on the international diffusion of technology (Saggi, 2002; Keller, 2004). This literature has identified three channels through which new technology flows and where patent protection is frequently used: trade in goods, foreign direct investment and licensing (Smith, 2001; Eaton and Kortum, 2002; Branstetter et al., 2006). Work in this area has also sought to explore the domestic conditions which facilitate and impede the (successful) diffusion of new embodied and disembodied technological knowledge.

Second, our paper relates to the literature investigating the links between environmental policy and the cross-border diffusion of ESTs. Empirical work on this topic has mainly relied on survey data (Veugelers, 2012), CDM projects data (Dechezleprêtre et al., 2008; Schmid, 2012) and patent data (Dekker et al., 2012; Haščič et al., 2010; Haščič and Johnstone, 2011a; Popp et al., 2011; Verdolini and Galeotti, 2011). None of these papers analyses the impact of relative regulatory stringency (regulatory distance) on technology diffusion.

The paper is structured as follows. Section 2 develops our arguments regarding the relationship between environmental regulation and the international diffusion of technology. Section 3 explains why the automobile sector constitutes a good test-case for our hypotheses. Data are presented in Section 4 and the research design described in Section 5. Section 6 presents the results and robustness tests. A final section concludes.

2. Environmental regulation, innovation and international technology diffusion

The past two decades have witnessed a surge in inventive activity aimed at reducing the environmental impact of production and consumption activities (OECD, 2011; Bettencourt et al., 2013). A leading driver for the innovation of ESTs has been environmental regulations governing processes and/or products (Costantini and Mazzanti, 2012). A number of studies find compelling evidence that various measures of regulatory stringency are positively correlated with innovative inputs as measured by R&D expenditures (Jaffe and Palmer, 1997; Lanoie et al., 2011) and innovative outputs as measured by patents (Brunnermeier and Cohen, 2003; Johnstone et al., 2010; Lee et al., 2011).

The literature identifies several actors ("inventors") involved in the innovation of ESTs. One is producers whose processes or products are the subject of environmental regulation (Bergquist et al., 2013). A second set of actors are suppliers who sell ESTs in embodied or disembodied form to other firms (Perkins, 2007; Taylor et al., 2003; Horbach, 2008)[4]. Some of these firms specialise in ESTs, while others supply environmental technologies as part of a wider range of equipment, including ESTs integrated into process designs. A third set of actors are publicly-funded research facilities and universities which are known to play an especially important part in the development of more radical technologies.

While environmental regulation may drive the innovation of new ESTs, as well as provide an economic incentive for regulated parties to adopt these technologies, the question addressed in the present paper is whether it also plays a role in EST diffusion across borders. The answer is likely to depend, in part, on whether there exists pre-existing technologies abroad to supply regulation-induced demand. In the case of regulatory leaders (i.e. those who lead in the introduction of the most stringent policy), regulatory tightening may well be supplied by domestic innovation, not least because there is no sufficient supply of compliance technologies abroad. While demand-side incentives in one country may of course stimulate innovation in other countries and thus increase the supply of foreign ESTs potentially available to domestic adopters (de la Tour et al., 2011; Peters et al., 2012), evidence suggests that the impact of domestic policies on innovation is much stronger than that of foreign policies (Dechezleprêtre and Glachant, 2014). Available case-study evidence therefore shows that the adoption of stringent regulation in regulatory leader countries has stimulated predominantly domestic innovation of ESTs in various sectors (Beise and Rennings, 2005; Brandt and Svendsen, 2006; Popp, 2006).

However, once a particular compliance technology has been domestically developed to comply with a specific domestic standard, the adoption of similar environmental standards elsewhere may lead inventors to transfer their technology to these jurisdictions (Beise and Rennings, 2005; Huber, 2008). Inventors in early-regulating ("frontrunner") source countries are likely to possess a competitive advantage vis-à-vis potential domestic competitors in later-regulating ("follower") countries, stemming from the fact that their pre-existing compliance technologies benefit from dynamic scale economies and learning effects (Porter and van der Linde, 1995; Brandt and Svendsen, 2006). This provides an

[2] Our results are robust to using all filed patent applications, however.

[3] Note, we use the terms source and inventor country interchangeably.

[4] Note, the distinction between these first two categories may sometimes be blurred, in that some regulated firms may sell their inventions to others firms (e.g. through licencing).