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Analysis

Policy design and technological substitution: Investigating the REACH regulation in an agent-based model

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ABSTRACT

This article proposes an agent-based model to study the impact of the European regulation REACH on industrial dynamics. This new regulation was adopted in 2006 and establishes a new philosophy of how to design environmental protection and health, especially through the authorization process and the extended producer responsibility. The main contribution of this article is to investigate how different combinations of flexible and stringent mechanisms create the incentives and constraints to shape market selection and innovation. The model outcomes stress that (1) stringency is the most determining feature of policy design (timing is also decisive but it appears to be of secondary importance); (2) technology substitution that brings radical technological change and significant pollution reduction is possible only if regulation is stringent enough but after many sacrifices, especially in terms of market concentration and number of failures; and (3) soft regulation does not lead to technology transition because of weak incentive and selection effects.

1. Introduction

In 2006, after a long legislative battle, the European Union (EU) adopted the REACH regulation (Registration, Evaluation and Authorization of Chemicals),[1] one of the most ambitious regulations ever implemented in Europe. This regulation introduces a new legislative philosophy about how to handle chemicals, especially by adopting three essential principles: the "*principle of reversal of the burden of proof*" from authorities to industry by which manufacturers and importers of chemicals must register each substance[2] and assess the health and environmental risks associated to avoid being excluded from the market ("No data, no market"); the *extended responsibility to users*, which is now closely associated with regulatory compliance, potentially widening the impact of REACH to all the industries; and the *authorization and restriction* of the most dangerous substances.

According to the third principle, public authorization is required for the production and use of chemicals considered to be especially worrisome – so-called substances of very high concern (SVHC) – "with the aim of substituting them" (REACH, article 55). SVHC are to be gradually identified and prohibited for sale and use after a set date (the so-called sunset date) unless the company is granted special authorization.[3] Thus, in the REACH regulation, the precautionary principle is complemented by a substitution principle.

From the start, REACH was designed to balance environmental objectives with competitive aims, and has the scope to induce the development and adoption of eco-innovation[4] as a side effect of the regulation itself. In the economic literature, many authors have emphasized a positive correlation between innovation and environmental regulation (Jaffe et al., 2003; Porter and van der Linde, 1995; Rennings, 2000). However, eco-innovations cannot be considered a systematic response to regulation. Policy design ends up being essential to inducing the development of eco-innovations (Ashford et al., 1985; Hahn, 1989; Jänicke and Lindemann, 2010; Johnstone, 2007). In this respect, a number of criteria, such as stringency, flexibility, timing and credibility, are important factors to consider. REACH seems to fit perfectly in this context and appears to be a privileged object of study to analyze how policy design can stimulate eco-innovations.

This article presents an agent-based model that investigates the key principles and mechanisms of REACH. We show how different

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[1] Regulation (EC) n°1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).

[2] This regulation applies to substances used in quantities higher than one ton per year.

[3] All requests for authorization must be accompanied by a safety report and an analysis of alternatives.

[4] Eco-innovation (also called *environmental innovation*) can be defined as "*the production, assimilation or exploitation of a product, production process, service or management or business methods that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives*" (MEI report, 2007, p.7).

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combinations of flexible and stringent instruments designed for REACH regulation create incentives and constraints that shape market selection and innovation. In particular, the model is intended to assess to which extent authorization provisions on SVHC may lead to increased moves toward the substitution of those substances through the supply chain.

The article is organized as follows. Section 2 draws on the literature on environmental regulation and eco-innovation to bring into focus the main mechanisms of the REACH regulation that can stimulate innovation and substitution of chemical substances. Section 3 presents the model following the ODD+D (overview, design concepts, details + Decision making) protocol (Grimm et al., 2006, 2010; Müller et al., 2013). Section 4 presents baseline simulations and examines the impact of regulation on market dynamics by considering various configurations in the policy design. Section 5 provides some concluding thoughts.

2. The Potential Effects of Reach on Innovation

2.1. Environmental Regulation and Innovation

Theoretical and empirical analyses on the relationship between environmental regulation and innovation agree that eco-innovations are essentially "policy-driven" (Jänicke, 2012; Jänicke and Lindemann, 2010). According to Rennings (2000), standard determinants of technological change, that is, demand pull and technology push effects, play an important role in fostering eco-innovation, but they have to be backed by a third determinant called "regulatory push–pull effect." In fact, unlike traditional innovation, eco-innovation is characterized by a double externality in the innovation and diffusion phases. The lack of incentive and ownership of innovations identified by Arrow (1962) is thus reinforced by this double externality problem. For this reason, public intervention is essential and regulation is a key determinant of eco-innovation.[5]

We know from Porter and van der Linde (1995) that only well-designed regulations lead to innovation. In particular flexible regulatory policies give firms greater incentives to innovate and thus are better than prescriptive forms of regulation. In many instances, these innovations are likely to more than offset the cost of regulation. So policy design ends up by being essential to inducing the development of eco-innovations (Jänicke and Lindemann, 2010). Ashford et al. (1985) and Hahn (1989) have emphasized that regulators must be careful in the severity, flexibility, and timing of regulation. In the same vein, Jänicke (2012) argue that policy design in particular should be based on ambitious and reliable targets and provide a flexible policy mix supporting the innovation process from invention to diffusion.

The European Commission was very attentive to these criteria in the way REACH was designed. A combination of hard and soft laws was preferred so that REACH relies more on open-ended standards (Fuchs, 2011) that combine different criteria:

- *Stringent*[6]: the consequences of an incorrect application of the REACH regulation are serious and immediate because they result in exclusion from the market ("No data, no market").
- *Reachable*: Fuchs (2011) describes REACH as a pragmatic regulation that is both ambitious and realistic in its goals in order to represent a real incentive to undertake innovation.[7]
- *Flexible*: it is shown through open-ended standards, flexible and revisable guidelines, and other forms of "soft law." It was considered important that the system remained flexible in order to ensure its workability (Fuchs, 2011). Moreover, REACH promotes a mode of governance based on the idea of "self-responsibility." This approach involves giving more responsibilities to companies and more flexibility on how to achieve the goals (Fuchs, 2011). In total, these mechanisms can adapt to diversity, tolerate alternative approaches to problem solving, and make it easier to revise strategies and standards in light of evolving knowledge (Scott and Trubek, 2002).

2.2. Authorization Process and Extended Responsibility Principle

REACH exhibits several mechanisms that can promote innovation in the chemical industry (Berkhout et al., 2003; Eurostat, 2009; Nordbeck and Faust, 2003). In our model, we focus mainly on two crucial innovation-friendly mechanisms: the authorization process and the extended responsibility principle.

The authorization procedure for SVHC is connected to the principle of substitution. The purpose of authorization is to ensure that the risks from SVHC are properly controlled and that these substances are progressively replaced by other substances or technologies, provided they are economically and technically viable. The authorization procedure is based on several steps: (1) identification of substances, (2) request for authorization before the sunset date, (3) granting or refusing authorization, and (4) reviewing authorization.

The granting or refusal of authorization is based primarily on the existence of economically and technically viable alternatives. If there are economically viable alternatives, companies will no longer be allowed to use substances after the sunset date; otherwise, authorizations are granted *only if* firms prove that they carry out serious analyses of alternatives. In that case, authorizations are granted until a review date by which the holder of the authorization will have to resubmit an application. So firms are encouraged to maintain technology watch on alternatives.

We see that the process of authorization is characterized by different features that combine stringency (target thresholds for techno-economic performances of alternatives), timing (the sunset date), and flexibility (review date), but also pragmatism (cost–benefit analysis) in order to support the innovation process from invention to diffusion. The Eurostat (2009) report about the impact of REACH on innovation in the chemical industry asserts that the process of authorization is an added value in terms of innovation and competitiveness. The report stresses that REACH has had a positive impact on research into new substances because the number of registrations of new substances has increased in line with expectations before REACH was adopted.[8]

The second innovation-friendly mechanism in REACH is found in the extended responsibility to users, because they are now responsible for the compliance of their production factors to the requirements of the new regulation. According to Wolf and Delgado (2003), innovation in the chemical industry is influenced by many elements, including demand and supplier–client relationships. By extending the principle of responsibility, the aim of REACH is to get actors in the whole production chain to take into account the environmental impact of the activity and to change the demand of downstream users toward environmentally friendlier products.

Typically, REACH must stimulate the development and adoption of alternatives to organic solvents. Solvents have been highly regulated and the use of organic solvents in Europe is ruled by the EC Directive 1999/13/CE on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations (VOC solvents emissions directive). However, the impact of this

[5] In several empirical studies, regulation has been identified as an important determinant of eco-innovation: see, for example, Jaffe and Palmer (1997), Lanjouw and Mody (1996), and Popp (2005). For an overview, see the EEA technical report (2011).

[6] According to Ashford et al. (1985), a regulation is stringent "either (1) because it requires a *significant* reduction in exposure to toxic substances, (2) because compliance using existing technology is costly, or (3) because compliance requires a *significant* technological change" (p. 426).

[7] Pragmatism is also shown in other provisions, such as the multiple deadlines for phase-in substances, the collective setting of priorities under the authorization and restriction processes, the various exemptions incorporated in the regulation, and the limited risk assessment requirements for substances placed on the market in proportions of less than 10 tons.

[8] In a recent report (2013), the European Commission notes that "increased obligations on SVHC through the Candidate listing and Authorisation provisions have led to increased moves toward the substitution of those substances through the supply chain" (p. 4).