ECO-INNOVATION AND REGULATORY PUSH/PULL EFFECT IN THE CASE OF REACH REGULATION: EMPIRICAL EVIDENCE FROM SURVEY DATA

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Eco-innovation and Regulatory Push/Pull Effect in the Case of REACH Regulation: Empirical Evidence from Survey Data

N. ARFAOUI


Abstract: Numerous theoretical and empirical studies show a positive correlation between eco-innovation and environmental regulation. However, very few analyses explain how environmental policies drive eco-innovation. This paper tries to fill this gap by studying eco-innovation-friendly mechanisms in the way the European REACH (Registration, Evaluation, Authorization and restriction of Chemicals) regulation has been designed. The aim of REACH, which entered into force in 2007 is “to ensure a high level of protection of human health and the environment while improving competitiveness and innovation”, which makes it an appropriate subject for analysis of the relation between regulation and eco-innovation. The study uses data from a unique original survey, which identifies innovation-friendly mechanisms in relation with the push/pull effect of regulation on environmental innovations. Our results show that extended responsibility of producers has a positive impact to “pull demand” toward environmental innovation. Moreover the obligation to exchange information along the supply chain and the process of authorization play an important role to “push” environmental innovation.

Keywords: Eco-innovation, REACH, Regulatory Push/Pull effect, Econometric modeling

JEL codes: Q55, Q58, C51

1. Introduction

The chemical industry has a prominent role to play in the management of environmental and health risks through its activities of supplier to a wide range of industries that produce final and intermediate goods. Especially any change in the environmental footprint of the chemical sector has an indirect impact on downstream industries. For this reason, the chemical industry is one of the most heavily regulated industry.

In 2006, the European Union (EU) adopted REACH (Registration, Evaluation and Authorization and restriction of Chemicals) regulation, one of the most ambitious and stringent regulation adopted so far in Europe. REACH introduced a new legislative paradigm related to how to handle chemicals and implement systems for their registration, evaluation, authorization and restriction.

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The central step of this system is the Registration phase. Since 1 June 2008, firms that manufacture, import or use chemicals in quantities of more than 1 tonne per year must be registered in a central database managed by the European Chemicals Agency (ECHA). This information is accessible to firms, individuals and non-governmental organizations (NGOs).

Firms must provide technical files containing physico-chemical, toxicological and eco-toxicological data, otherwise without data, companies cannot use the substances: “No data, no market”.

The second step of the system is the Evaluation phase. Firms using quantities of more than 10 tonnes per year must provide an evaluation of the associated health and environmental risks.

REACH applies a regulatory “principle of reversal of the burden of proof” from authorities to industry by which firms are responsible for demonstrating the safety of their products. Such a principle extends responsibility also to users, whose production must respect the regulatory requirement. Downstream users are thus closely associated with regulatory requirements and they must actively support the efforts of producers of substances. So REACH does not apply only to the chemical industry but concerns all the industries. REACH introduced also an information transfer mechanism through the supply chain. Production and transmission of information are based on the Safety Data Sheets (SDS) and on organizational structures made for sharing and pooling the information within Substance Information Exchange Forums (SIEFs) or Consortia.

Finally REACH introduces a process of Authorization and restriction to the most dangerous substances. Public authorization is required for the production and use of chemicals considered being especially worrisome: so-called substances of very high concern (SVHC) "with the aim of substituting them".

Under the preamble of the regulation n°197/2006 the explicit goal is “to ensure a high level of protection of human health and the environment while improving competitiveness and innovation”. REACH has been designed to balance environmental objectives with competitiveness aims, and has the scope to induce the adoption of eco-innovation as a side-effect of the regulation itself.

In the economic literature many theoretical and empirical studies show positive correlation between eco-innovation and environmental regulation (Porter and van der Linde, 1995; Lanjouw and Mody, 1996 Rennings, 2000; Jaffe and al., 2003, Horbach, 2008). However as underlined by Kemp and Pontoglio (2011), “more research should be done on how environmental policies influence the direction of innovation and compliance choices”. The aim of this paper is to try to fill this gap by studying innovation-friendly mechanisms present in the REACH regulation to “push” and “pull” environmental innovations. REACH appears to be a privileged object of study to analyze the relation between regulation and eco-innovation. However, both empirical and theoretical literature about the impact of REACH on innovation is still very scarce because the implementation phase is an on-going process. Moreover it is difficult to carry out impact assessment studies because of a lack of data. This paper presents the results of an econometric study based on data collected from an original survey on REACH regulation. This survey has been carried out from December 2012 to December 2013 and has drawn 196 responses from chemical firms located in PACA region. The objective of the survey is to clearly highlight which innovation friendly mechanisms attached to REACH may have an impact on eco-innovation and how such mechanisms influence the eco-innovation process. This paper contributes to better understand the “doubly regulatory effect” (Rennings, 2000) on eco-innovation. The paper is organized as follows. Section 2 presents the main theoretical hypothesis we will test concerning the impact of REACH upon eco-innovation. Section 3 presents the econometric
model. Section 4 summarizes the main results and gives some policy recommendation.

2. Theoretical framework and research hypotheses.

Theoretical and empirical analyses on the relationship between environmental regulation and innovation agree that eco-innovations are essentially “policy-driven” (Jänicke, 2007, Jänicke and Lindemann, 2010). According to Porter and van der Linde (1995) environmental regulation will stimulate innovation and improve the competitive position of companies. A strict regulation will on the one side increase firm’s abatement expenditure. On the other side, these additional costs will push companies to overhaul their production processes and therefore to innovate. Innovation offsets can lead to a win-win result. Indeed, in order to ensure compliance with regulation, firms undertake innovative actions, that will not only protect the environment, but will also allow them to have new business opportunities and to enhance their competitiveness. According to Rennings (2000), eco-innovation is characterized by a double externality in both the phases of innovation and diffusion. The lack of incentive and ownership of innovations identified by Arrow (1962), is thus reinforced by the double externality problem. Therefore, even if the traditional determinants demand-pull and technology-push play an important role, eco-innovations are driven by a double regulatory effect, called “Regulatory push-pull effect” (Rennings, 2000).

For Nordbeck and Faust (2003) and the authors of SRU (2003) innovation is the most important advantage of the REACH regulation. By emphasizing the protection of health and the environment REACH provides a signal to the direction for future research and innovation towards sustainable development. Eurostat (2009) report shows that a number of innovation-friendly mechanisms in the chemical industry are present in REACH. Another empirical study providing an interim evaluation of the impact of REACH on the innovativeness of the European chemical industry (CSES, 2012) stresses also that REACH “will create new opportunities and demand for the development of new safety substances.” (CSES, 2012 p.12). We thus can consider that REACH has been designed to “push” and “pull” environmental innovations.

2.1. The regulatory-push effect of REACH regulation

REACH tends to create new technological opportunities for environmental innovation by reducing the private cost of producing them. Nemet (2009) distinguishes two types of techno-push policy. First policy affecting the size of the market, and second policy directly influencing the supply of new knowledge. To “push” eco-innovation REACH uses both strategies. On one hand REACH creates “learning spaces” for new environmental technologies by stimulating internal and external information sources, on the other hand REACH influences the size of the market by removing barriers to innovate.
2.1.1 Internal and external information sources within REACH

The evolutionary approach of technological change considers that information and knowledge are at the basis of innovation activities (Nelson and Winter 1982; Pavitt, 1984; Dosi, 1988; Malerba, 2005). Innovation is defined as the process of creation of new technological knowledge and competence. According to Malerba (2005), the knowledge base is "relevant for an explanation of the rate and direction of technological change, as well as of the organization of innovation and production". The knowledge base depends on learning processes that are firm specific insofar as based on the capacity of firms to develop and to acquire new knowledge (Malerba and Orsenigo, 1996, 1997). The knowledge base is characterized by different degree of appropriability and different sources of information (internal or external), which are involved in the learning process of the firm.

In order to enhance the capacity of firm to develop new competence and knowledge in environmental technologies, several authors (Hahn, 1989; Elzen et al, 1996, Kemp, 2000) call for adopting environmental regulation that creates a new « learning space » in the environmental technologies by developing new sources of internal and external information. REACH seems to fit perfectly to this context since the regulation has led to “an increase in the information base of the chemical industry” (p.xi) according to the CSES report (2012).

In a first place REACH tends to stimulate internal sources by supporting R&D activities. In the economic literature R&D activities are considered as insufficient condition to innovate (Åkerblom, Virtaharju and Leppäahti, 1996; Felder et al 1996), but their contribution is important in the innovation process. R&D activities represent important internal sources of information in the firm. Firms that have a powerful R&D program are more likely to innovate for different reasons. First R&D expenditures allow firms to develop and accumulate knowledge in order to create new products and processes. Second, firms that perform R&D are also more willing to use technological advances of others (Mowery and Rosenberg, 1989). Even if the role of R&D in eco-innovative activities is not well documented, Scott et al (2003) show the important role of R&D in eco-innovative activities. REACH tends to support R&D activities through different mechanisms. The first one is the volume exemption for R&D. Actually REACH forces all the substances produced or used to be registered and evaluated. However REACH provides an exemption for the substance in quantity less than one ton per year used in the R&D activities. So firms can use substances for scientific experimentation, analysis or research without the obligation of registration, evaluation and authorization process. The second pro-R&D mechanism is the product and process oriented research and development (so called PPORD). PPORD allow firms to use substances in the scientific research process without registration during five years. To qualify for the exemption, firms must submit a PPORD notification to the European Chemicals Agency with the identity and classification of the substance, the estimated amount and the list of clients. Upon request, the agency may extend this exemption for a further period not exceeding 5 years.

The third mechanism stimulating R&D activities lies in the authorization process. The aim of the authorization process is to substitute the production and the use of chemicals especially worrisome so-called substances of very high concern (SVHC). SVHC are to be gradually identified by a Member State or the European Commission and are included in the 'Candidate list' and eventually included in Annex XIV of the REACH Regulation. Once included in that Annex, they cannot be placed on the market or used after a date to be set unless the company is granted an authorization. The granting or refusal of authorization is primarily based on the existence of economically and
technically viable alternatives. So, in the event that there are economically viable alternatives, companies will no longer be allowed to use substances after the sunset date. However if there are no technically and economically viable alternatives, authorizations are granted only if firms prove that they carry out serious analyses of alternatives. So, under Article 5 of the regulation, all request of authorization must be accompanied by a safety report and an analysis of alternatives with information about activities of R&D. Moreover authorizations are granted for a period and can be reviewed, at any time, if new information on possible substitutes is available economically viable. So firms are encouraged to stimulate alternatives R&D activities and to maintain technology watch. By emphasizing the protection of health and the environment REACH provides a signal as to the direction for future research towards sustainable development. All these elements suggest the following hypothesis:

**H1: REACH stimulates internal R&D activities**

In a second place, REACH tends also to stimulate external sources of information by “enhancing the capacity of external information exchange” (Nemet, 2009) with the goal to develop environmental innovation. According to CSES report (2012), REACH introduced industrial information transfer mechanisms aimed at capturing and disseminating data, across industries and through the supply chain, to stimulate the development of safe chemicals and practices. The goal is to support innovation because information and knowledge are considered to be at the basis of innovation activities. Knowledge and competence involved in the learning process can be internal or external to the firm. The interactions between firms and the external environment (with suppliers, competitors, universities and public research) are essential in interdependent and complex innovation processes. So the ability to exchange external information is important to overcome incomplete information within a firm, to facilitate coordination of innovation activities and to enhance their capacity to innovate. This aspect has been pointed out by Porter and van der Linde (1995) also for eco-innovation. The authors show that “if environmentally and economically benign innovations are not realized it’s because of incomplete information, and organizational and coordination problems” (Horbach, 2012).

In the chemical industry the link between internal and external sources of information is particularly important for successful eco-innovation. In fact the skills to develop environmental innovations are often located outside the polluting industry (Cesaroni et al 2009, Kiriyama 2010). Successful environmental innovation requires new combinations of knowledge about product characteristics, process and material characteristics, and available technologies and markets. The exchange with the external environment of a firm is a key to successful environmental innovation (Sarkis, 2004). Some empirical studies (Mazzanti et al 2005, Kemp et al 2009, Belin et al 2011 De Marchi, 2012) analyze the issue of information used to eco-innovate. They show that external information positively influences adoption of eco-innovation, and that eco-innovation require more strongly external sources of information. According to Horbach et al (2011) “policy instruments must help firms to overcome information barrier”. In this perspective, REACH introduces mechanisms that contribute to an external exchange of information, based on:

- The registration and evaluation dossiers,
- The Safety Data Sheets (SDS),
- The transmission of information through the supply chain,
- The Substance Information Exchange Forum (SIEFs) or Consortia.
Through the process of registration and evaluation of chemicals, firms are forced to provide all existing data on the properties of the chemicals they use. Without data, companies cannot use the substances: “No data, no market”, summarizes ECHA. So registration and evaluation dossiers must contain a technical dossier with physicochemical, toxicological and eco-toxicological data and a chemical safety report. Moreover these information must be part of Safety Data Sheets (SDS) that accompany the substance. By forcing the provision of information, it is expected that this information may bring a new knowledge that could stimulate new ideas (CSES report, 2012).

REACH implements also the obligation to communicate the information through the supply chain. In fact REACH concerns the manufacturer of the substance and the downstream user, which is now responsible for the compliance of their factors of production to the requirements of the new regulation. So communication through the supply chain is essential in REACH. The information must be transmitted by manufacturers to downstream users, and in turn from downstream users to manufacturers. The obligation to exchange information is not a temporary but a continuous obligation, whenever information changes. Suppliers are required to communicate information to downstream users for the registration number, authorization and restriction of components and any other information about chemical safety report. Downstream users have to communicate on their uses so that suppliers can introduce them in the exposure and risk management measures described in the scenario. Moreover downstream users have to check and make sure that their suppliers have registered the substances according to the uses identified. If the exposure scenario described in the registration dossier does not cover the own use of a substance, the downstream user cannot use the substance. The user must notify his own account. With the obligation to communicate information along the supply chain, REACH tends to introduce an environmental supply chain management (EMS) in order to stimulate eco-innovation (Wagner, 2007, Kesidou et al, 2012). The environmental supply chain encompasses all value chain activities based on the information flow and transformation of goods from extraction of raw materials, to the product end use. The goal is to define and evaluate the total environmental load associated to products. Supply chain management allows the coordination of these activities in order to improve supply chain relationships to achieve a sustainable competitive advantage (Seuring et al 2008). For Greffen and Rothenberg (2000) supply chain management is an important source of information to enhance radical environmental innovation. According to the CSES report (2012), ‘closer contacts between users and suppliers, better external linkages and access to external sources of knowledge… could improve the direction and pace of innovation as well the development of newer and safer products’. (p.29)

Finally to facilitate the exchange of external information REACH has created a transitional regime implementing the Substance Information Exchange Forum (SIEFs) or Consortia. The SIEF function is to bring together manufacturers, importers and downstream users to exchange information covered by one and the same substance. The SIEF organizations designed in REACH are likely to increase knowledge and make information available on existing market opportunities. They might stimulate innovation both leading to new ideas for the development of new products or for the use of existing substances and creating new collaborations (Wolf et al 2003). Given what we have just exposed, we propose the following hypothesis:
2.1.2. Barriers to innovation and REACH

The economic literature relates innovation to the existence of sunk costs. Sunk costs are expenses incurred to enter a market or industry that it is not possible to recover once getting out the industry in the event of failure. Any potential entrant take these costs into account and to some extent they constitute barriers to innovation. In the chemical industry sunk costs result essentially from the registration and evaluation processes which are time-intensive and costly, thus creating barriers to develop new substances (Wolf and Delgado, 2003).

REACH tends to remove the cost barriers by reducing the registration and evaluation costs. Firstly REACH put an end to the dual-track system that used to exist between old and new substances. In fact before REACH only new substances could be registered and evaluated, so it was costly to develop a new substance. This distinction between new and old substances creates barriers to the development of radically new substances because it is more costly (Wolf and Delgado 2003, CSES 2012). Firms are more willing to create new products from existing substances rooted in the petrochemical paradigm, since there was no need to register and evaluate the substance. Since REACH has entered into force in 2007 there is no more distinction between existing and new substances. All substances must be registered and evaluated. The aim is to spur firms to develop new substances in an alternative cleaner paradigm. The return on investments of new safer substances is expected to be higher because these substances have less probability to be included in the list of SVHC substances and to be prohibited. Secondly REACH introduces the possibility of using the results of tests carried out by other firms, thus allowing to reduce the registration and evaluation costs REACH implements joint submissions in order to share the costs and to avoid the duplication of tests including those involving vertebrate animals. When a substance is manufactured or imported by more than one firm, firms have an obligation to provide a joint submission for the registration of the substance. Consecutively firms will benefit from a reduced registration fee and they can share the costs of tests. For each substance with a joint submission, other firms need only to refer to this registration and to provide data on the characteristics of its production or its use.

Finally REACH tends to reduce the length of the registration process, which impacts the time-to-market of the substance and represents a barrier to innovation. In some markets such as cosmetics time-to-market has a significant impact on the development of new substances because the market is changing rapidly and it is not possible to introduce products with too much time. In other cases, the recording of some substances like polymers or isolated intermediates, increase the time to market of new substances (Nordbeck et al 2002, Wolf et al 2003). Indeed, an article may contain several isolated intermediates or polymers

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2 The first European environmental regulations appear in the early 1980s. The objective of these regulations is to make an inventory of existing chemicals. The European Union has implemented EINECS (European Inventory of Existing Commercial Chemical Substances). In 1981, the only time that chemicals have been identified in the EU, there were 100,106 on the market (Diderich, 2011). The regulations provided that any substance, which was listed in the inventory, was considered a new substance. This should be recorded and evaluated by industry before being placed on the market. The authorities evaluated existing substances when there is scientific doubt in their harmfulness.
and the obligation to notify each of them increases the time to market. However intermediate substances are produced only for the synthesis of other chemical substances, and polymers are substances whose structures are mainly due to the repetition of units of low molecular weight. These substances are not considered to be of health and environment concern.

So REACH introduces an exemption for polymers and intermediates in quantities up to 1 ton per year. These exemptions meet the needs expressed by the chemical industry, and will remove one of the main barriers to innovate in this field (Nordbeck et al. 2002; Wolf et al. 2003). We propose the following hypothesis:

H3: REACH reduces the cost barrier and the market access barrier.

2.2. The regulatory-pull effect on REACH regulation

The literature on environmental innovation also stresses the role of demand for eco-innovation (Florida, 1996, Popp et al 2007 Horbach, 2008). According Wolf (2003), innovation in the chemical industry is influenced by many factors, especially by the demand and supplier-client relationships. In several activities such as treatment surface activities demand can be an obstacle to the development and the diffusion of eco-innovation (Belis-Bergouignan et al., 2004). Florida (1996), Popp et al. (2007) and Horbach (2008), show that demand is essentially driven by public pressure. In fact in the case of eco-innovation and contrary to classic innovation, demand-pull effects are strongly supported by environmental policies.

REACH implements different mechanisms in order to modify the intrinsic and external motivations of clients toward cleaner products. The first mechanism is the principle of extended responsibility to users. In fact downstream users are now responsible for the compliance of their factors of production to the requirements of the new regulation. They are closely associated with regulatory compliance, by actively supporting the efforts of manufacturer of substances. By extending the principle of responsibility, the aim of REACH is to place the environmental impact of the activity throughout the production chain, in order to change the demand of user downstream chemical products towards more environmentally friendly (Arfaoui et al, 2013).

Sustainable economics involves a structural approach of product life cycle to define and evaluate the total environmental load associated to a product. For Sarkis (2004) life cycle must be based on the sharing of environmental responsibility for achieving a reduced environmental burden caused by industry. By extending producer responsibility, policies impose responsibility for the product end-of-life and encourage producers to change their products and thus to develop eco-innovations (Brouillat et al, 2012; Lindhqvist, 2000).

The second mechanism tends to increase the information concerning chemicals. According to Rennings (2000), consumer willingness to pay for environmental improvements is low. Environmental innovations are characterized by the existence of another type of market failure due to the lack of reliable information on the environmental and health quality goods. The reason for such a market failure relates to the concept of information asymmetry put into light by Akerlof (1970). The quality of a credence good (Darby and Karni, 1973) is difficult to assess by consumers, even after its consumption. Environmental
quality and health considerations are characterized by these properties attached to credence goods.

It is difficult for consumers to find reliable information ex ante, and difficult to validate this information even after consumption, except in the very long term. Most of the time, a consumer is not able to assess the environmental and health quality of products. The consumer therefore faces a strong and often persistent uncertainty on the environmental quality of the product they are buying. Akerlof (1970) shows that the presence of asymmetric information between producers and consumers about the quality of the product, may lead superior products to be "driven out" from the market by inferior products (adverse selection).

Consumers are not willing to pay more for products with higher environmental quality and health benefits on which they cannot be certain. This information asymmetry can represent a barrier to environmental innovation. The chemical industry is particularly subject to asymmetric information. In 1980 there were 100 000 substances on the market. According to the European commission (2009) for nearly 21% there are no data at all, nor on physicochemical properties, or the environmental and health risks. Only 3% have been fully tested and for which complete information is available.

REACH tends to increase the access and scrutiny of information about chemical substances (Béal et al 2013). Firms must register and evaluate all the substances and post such data in a central database managed by ECHA. This process is extremely important since the aim is to evaluate the intrinsic properties of chemical substances to identify hazards to human health and the environment, in order to communicate this information to the user. This information is accessible to both firms and individuals or NGOs on the ECHA website. Information is also transmitted through the classification and labeling process of chemicals. This process tends to classify hazards according to their importance and represent the first information communicated to the user. By introducing openness and scrutiny, more knowledge about substances is likely to be accessible, which would in turn drive the demand towards more environmentally friendly substances. We can thus propose the following hypothesis:

**H4: REACH modifies the demand toward eco-innovation**


3.1 Data and descriptive statistics

The data we use in the empirical study are based on a unique survey on REACH administered to chemical firms in the PACA Region (France). The survey aims at analyzing the impact of REACH on innovation in the PACA region, particularly in the field of health and the environment. The objective is to explain how different mechanisms of REACH impact the process of innovation in the field of environment and health, from invention to commercialization of innovation. The definition of eco-innovation used in the survey is inspired by the one applied in the CIS 2010 survey. This definition follows itself the concept developed in the MEI project (2008) wherein the aspects of the environment and health are introduced.

So in the survey an eco-innovation is defined as :
“a new or significantly improved product (good or service), process, organizational method or marketing method that creates environmental and health benefits compared to alternatives. The environmental and health benefits can be the primary objective of the innovation or the result of other innovation objectives. The environmental health benefits of an innovation can occur during the production of a good or service, or during the after-sale use of a good or service by the end user.”

The creation of a relevant sample was performed in direct collaboration with the PRIDES Novachim cluster. PRIDES Novachim is the regional cluster that brings together firms in the chemical sector. This cluster is highly mobilized in assisting firms in the implementation of the REACH regulation. Therefore it was naturally the best way to mobilize their members around a questionnaire on REACH.

The anonymous survey was conducted online between December 2012 and December 2013 and has enabled to obtain 196 usable responses. The sample can be considered to be representative since it represents 32% of the chemical firms present in the region (see INSEE 2011) and is close to the threshold of one third of respondents generally considered satisfactory. This sample is also representative in terms of firm size since 62.24% are constituted by firms employing 1 to 9 persons (against 65% according INSEE), 22.45% by firms employing 10 to 49 persons (against 19% according INSEE), 10.20% by firms employing 50 to 249 persons (against 9% according INSEE) and 5.10% by firms employing more than 250 persons (against 7% according INSEE).

Table 1: Distribution by firm size

<table>
<thead>
<tr>
<th>Size</th>
<th>Freq</th>
<th>Percent</th>
<th>Cum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-9</td>
<td>122</td>
<td>62.24</td>
<td>62.24</td>
</tr>
<tr>
<td>10-49</td>
<td>44</td>
<td>22.45</td>
<td>84.69</td>
</tr>
<tr>
<td>50-249</td>
<td>20</td>
<td>10.20</td>
<td>94.90</td>
</tr>
<tr>
<td>&gt;250</td>
<td>10</td>
<td>5.10</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>196</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Table 2 shows the distribution of respondents as they have introduced or not eco-innovations to comply with REACH.

Table 2: Eco-innovations as a response to REACH

<table>
<thead>
<tr>
<th>EI</th>
<th>Freq</th>
<th>Percent</th>
<th>Cum</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>86</td>
<td>43.88</td>
<td>43.88</td>
</tr>
<tr>
<td>1</td>
<td>110</td>
<td>56.12</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>196</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

We can see that 56.12% of firm has introduce eco-innovation in response to REACH regulation.
3.2 Econometric analysis

Following our theoretical considerations and hypotheses on the determinants of eco-innovation, two main sets of variables are distinguished: those related to regulatory-push mechanisms and those attached to regulatory-pull mechanisms.

The first set of variables enables to capture R&D activities, information sources and cost and market access barriers.

For R&D activities we consider R&D expenditures (RD) undertaken since the introduction of REACH. We have also included R&D exemption (RDExp), the process oriented research and development (PPORD) and the process of authorization (Autho) which are all specific to REACH. As information sources we take into account the Registration dossier (R-Dossier), FDS, SIEF, and the influence of the different sources (publicinfo, supplierinfo, consultinfo, competitorinfo).

Cost barriers and market access can be approached by the following variables: the end of the dual-track system between old and new substances (New/Old), the impact of the joint test (Test), and the impact of isolated intermediates and polymers exemption (Intermed Exp, PolyExp).

Regarding the second set of variables, we consider the role of information in the hands of clients (Clientinfo) and the extended responsibility principle (ExtendResp).

Control variables are used to account for difference in size and activities within the supply chain of chemicals. Furthermore, in order to account for the diversity of roles played by chemical firms, we make a distinction between Research and Development organizations (including Contract Research Organizations), Manufacturers of chemical substances, Importers of chemical substances or mixtures, Formulators (mixer) of chemical substances or mixtures, Producers of articles that contain chemical substances, Importers of articles that contain chemical substances, Distributors/retailers of chemical substances, mixtures or articles that contain chemical substances intended to be released and End users of chemical substances or mixtures.

Table 3: Variables

<table>
<thead>
<tr>
<th>Technology Push mechanisms</th>
<th>Demand Pull mechanisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothesis</td>
<td>Variables</td>
</tr>
<tr>
<td>H1: REACH stimulates R&amp;D activities</td>
<td>RD, RDExp, PPORD, Autho</td>
</tr>
</tbody>
</table>
In our analysis we used a probit model (Green, 2008) due to the fact that the dependent variable is binary. The binary probit model can be described as follows: the firm has to decide whether to introduce an environmental innovation in response to REACH (Y = 1), or “not” (Y = 0). Therefore, we need an estimation of the following probability:

Prob (Y = 1| x) = F (x, β). Because of the binary character of our dependent variable, we use the probit model assuming the normal distribution:

Prob (Y = 1| x) = φ (x’ β). The parameters β reflect the impact of changes in x on the probability (Greene, 2008, p.772).

4. Results

Table 4 depicts the results of the probit regression fit.
Table 4

Dependent variable: Eco-innovation in response to REACH
1 if firm implemented Eco-innovation
0 if Not

Correlates Variables

<table>
<thead>
<tr>
<th>Correlates Variables</th>
<th>Marginal effect</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Probit regression</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Regulatory Push</strong></td>
<td><strong>Regulatory Push</strong></td>
</tr>
<tr>
<td>R&amp;D activities</td>
<td>R&amp;D activities</td>
</tr>
<tr>
<td>RD</td>
<td>-1.9 (0.028)*</td>
</tr>
<tr>
<td>RDExp</td>
<td>0.52 (0.278)</td>
</tr>
<tr>
<td>PPORD</td>
<td>1.01(0.14)</td>
</tr>
<tr>
<td>Autho</td>
<td>1.56(0.000)***</td>
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<td>Joint Test</td>
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<tr>
<td>Intermed Exp</td>
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<td>PolyExp</td>
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<td>Regulatory Pull</td>
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<td>Clientinfo</td>
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<td>Extendresp</td>
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### Control variables

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<td>Chemicals</td>
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<td>Contains chemicals</td>
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Probit regression:
Chi2 = 196. Pseudo R2 = 0.43.
Z-statistics are given in parentheses. ***, *** denote significance at the 10%, 5% and 1% level, respectively.

The results of the econometric analysis (see Table 4) show that the process of authorization plays an important role in triggering eco-innovation. This mechanism appears to be the major driver for eco-innovation as indicated by the marginal effect of the corresponding variable, which is the highest one (54%). This observation gives empirical support to the theoretical analysis of Berkhout.
et al (2003) emphasizing that the process of authorization is the most revolutionary aspect of REACH and represents the strongest mechanism to induce research into new substances. Our results are also coherent with one of the rare empirical studies providing an interim evaluation of the impact of REACH on the innovativeness of the European chemical industry (CSES, 2012). The report stresses that ‘the candidate list is a, if not the, major driver for change at present’ (p.xii) and that ‘authorization has had a similar effect to the candidate list although for a smaller group of firms which have been affected...’ (p.xii). According to Arfaoui et al (2013), the process of authorization has been designed to support the innovation process from invention to diffusion of alternatives. With such a mechanism REACH complements the precautionary principle by a substitution principle. The goal of authorization is to progressively substitute hazardous substances by other substances or technologies less hazardous to health and environment, when there are alternatives economically and technically viable. In case there are economically viable alternatives, public authorities prohibit the use of this substance. Firms are forced to find alternatives because companies will no longer be allowed to use substances after the sunset date. However in the case there are no economically viable alternatives authorizations are granted only if firms prove that they carry out serious analyses of alternatives. In fact all requests of authorization must be accompanied by a safety report and an analysis of alternatives with information about activities of R&D. In that case, authorizations are granted case by case until a specific date by which the holder of the authorization will have to resubmit an application. Review dates are driven by the information provided by the applicant, in particular the substitution plan and the analysis of alternatives. To renew an authorization, a revised report must be sent to ECHA before the expiry date of the time-limited review period defined in the authorization decision. Meanwhile, the authorization may be reviewed or suspended by the Commission at any time, if information regarding possible replacement substances becomes available. We observe in all cases that firms are encouraged to develop R&D activities and to maintain technology watch on alternative substances. The RD exemption has no significant impact on the adoption of eco-innovation. This result can be explained by the fact that the exemption is limited in quantities up to 1 ton per year and this volume limit of 1 ton seems to be insufficient to conduct R&D activities particularly for the development of pilot, trials and early production introduction (CSEC, 2012).

As well the process oriented research and development (PPORD) does not appear to have a significant influence. Several firms have explained not using this process because it is costly and lengthy. Moreover the request is treated in a discretionary way by ECHA because authorizations are granted case by case and firms are not certain to get an agreement.

Concerning the impact of REACH on R&D expenditures the results are quite interesting because the increase in R&D expenditures has a negative effect on eco-innovation. This result is in line with Horbach et al (2011) who show that in the case of eco-innovation, firms do not need to invest in R&D to increase their capacity to innovate. This result underlines that R&D is not the most important source for eco-innovation. Instead it corroborates the fact that eco-innovations require more external sources of information.

As regard the impact of REACH on the external sources of information, the results show that the obligation to communicate information through the supply chain has a positive influence on eco-innovation. This result is in line with the
idea that eco-innovations are influenced by external information and more particularly by the supply chain information. Our result are coherent with several studies like Khanna et al. (2009), Rehfeld et al. (2007), Rennings et al. (2006), Wagner (2008) and Horbach (2012) which demonstrate that the supply chain information is highly correlated to eco-innovations. As shown in the Eurostat (2009) report and the CSEC report (2012) many companies state a positive impact of REACH on innovation because of that increased communication. This result can be explained by the fact that “the communication in the supply chain provides chemical companies with new information about customers and their needs” thus increasing their capacity to innovate. The obligation to transmit information in much deeper flows along the supply chain allows suppliers to gain detailed insights into the subsequent stages of the life-cycle and activates the supply chain as a way to comprehend why such improvements are required (Pesonen et al, 2001).

However competitors as a source of information have a significant but negative effect on eco-innovation.

Finally the other external sources of information have no significant impact on eco-innovation. In particular specific mechanisms put into place by REACH such as RDossier, FDS and SIEF are not important sources to eco-innovation. This result can be explained by the fact that the first registration period (2007/2010) concern large volume substances which eco-toxicological properties have been well known. In the registration process, there are different deadlines defined in terms of tonnage thresholds. The first registration phase was completed on 30 November 2010. It concerned substances produced or imported over 1,000 tons per year. The second deadline was 31 May 2013 for substances produced or imported at more than 100 tons per year. In the end the final deadline is scheduled for May 31, 2018 on substances from 1 to 100 tons. According to the CSES report (2012) RDossier, FDS and SIEF are expected to play a more important role as sources of information for eco-innovation in the last period of registration, which concern with small volume and less known substances.

The econometric results show that REACH has no impact on cost barriers and market access since none of the corresponding variables (New/Old, Test, Intermed Exp, PolyExp) have any significant influence on eco-innovation. This result can be explained by different reasons.

First, the exemption for isolated intermediates is limited in quantities up to 1 ton per year and this restriction seems to have a negative impact on innovation. According to the CSES report (2012) “a lot of laboratory applications are often not covered by intermediate exemption and R&D users should be able to use and transported isolated intermediates without restriction”.

Second, regarding the exemption of polymers firms point the problem of polymer definition (CSES, 2012). REACH adopts a particular definition of a polymer which is different from the one used in most books of chemistry. Thus some materials, which are commonly called “polymers” or “polymeric”, do not

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3 According to Article 3 (5) of REACH a polymer is defined as a substance meeting the following criteria:
   a) More than 50% of the weight of the substance consists of polymer molecules. A "polymer molecule" is a molecule that contains a sequence of at least three monomer units *, bound by covalent bonds to at least one other monomer unit or other reactant
   b) The amount of molecules having the same molecular weight must be less than 50% by weight of the substance. The preferred method for identifying whether a substance is the definition of a polymer is the exclusion chromatography (gel permeation).
meet the definition of a polymer according REACH. Moreover though polymers are exempted from registration monomers and other reactants used to produce the polymer must be registered. However identification and quantification of the monomer content of a polymer, as required by REACH and the corresponding official technical guides are particularly difficult. It explains why “many hours are spent in the laboratory in order to resolve these formal problems, but it is still not innovative since the final properties are not improved” (CSES, 2012, p.47).

Third, the distinction between new and old substances is not clearly removed by REACH. According to the CSES report (2012), the difference between existing and new substances still exit under REACH. In fact for “new substances between 1-10 t/a, one has to provide the standard test data of Annex VII, whereas for "old" substances one doesn't have to, according to Annex VII (a) (b) and (c), unless according to Annex III they are likely to cause a risk. In addition REACH has brought new factors into play that create barriers for research activities on new substances.”(p.42).

Fourth, the joint submission has no significant impact on eco-innovation. This result can be explained by difficulties of access to data sharing. In the CSES report (2012) several SMEs emphasize the prohibitive price of letter of Access to allow data sharing. They also show the difficulty to check the quality of the information contained in this joint dossier. However dossiers still have to be evaluated by ECHA, which can reject it. So some firms explain its seems caution to do the tests themselves.

Finally it appears that REACH increases the time to market due to administrative process and test needs. Moreover the complexity of the regulation created the need to use R&D staff for compliance issues, and requirements of technical staff to monitor developments in various regulations and directives. Firms pointed out that although much of the activity could be considered administrative and bureaucratic the regulation requires input from staff with a solid grounding in chemistry and toxicology to ensure compliance. Other factors contributing to increase the time to market have been the inquiry process at ECHA to check the conformity of dossiers. There is no legal time limit owing to ECHA so “that it can take too long to obtain a reply/ a full inquiry process takes about 5-6 months” This can be a real barrier in the commercialization of innovation.

Concerning the impact of REACH on the demand toward eco-innovation, the extended responsibility has a significant positive impact on eco-innovation. This result gives empirical support to the theoretical relation between extended responsibility and eco-innovation (Walls, 2006; Fullerton and Wu, 1998; Palmer and Walls, 1999 Brouillat et al., 2012). This literature assumes that an extended responsibility will encourage firms to design environmental friendly products.

The clientinfo variable has no significant impact. This result stresses the idea that even if the information is more available, the information used for chemicals is complex. As shown in the CSES report (2012) the user client lacks scientific knowledge to understand all the information especially for small firms that do not have the appropriate human resources. Concerning SDS some firms explain that they are not always sure of the quality of that information. In addition, firms comment that the requested information is not always available. Moreover only some fraction of information is made publicly available through the SDSs (including exposure scenarios where applicable) and the ECHA website. Although made publicly available, much of the data is still owned by the consortia member companies. So some ONG emphasize the lack of transparency of ECHA, which refuses to disclose all the data.
Finally the econometric results for the control variables show that manufacturers of chemical substances and formulators of chemical substances introduce more environmental innovations than other firms with different activities in response to REACH. This result corroborates the idea that suppliers are an essential source for developing radical environmental innovations (Greffen et al 2000).

Regarding the size, results show that bigger firms have a significant and negative impact on the adoption of eco-innovations. This result can be explained by the fact that bigger firms were considered less flexible and less able to find a market niche. The CSES report (2012) emphasizes that despite the costs of implementing regulations “SMEs might be able to respond to some of these mechanisms relatively well because they are more flexible, and can respond quickly”.

5. Conclusion

This article intends to contribute to a better understanding of the “push-pull regulatory effect” on eco-innovation (Rennings, 2000). We study the REACH regulation adopted in 2006 with the aim of enhancing innovation in alternative chemical substances. Our analysis is based on an empirical survey on the way the innovation-friendly mechanisms designed in REACH are able to push and pull environmental innovations.

In order to push environmental innovation REACH tends to create new technological opportunities by reducing the private cost of developing eco-innovation. Therefore REACH tends both to create learning spaces for new technology and to influence the size of the market thus removing barriers to innovate. The creation of learning spaces for new knowledge is achieved by stimulating R&D activities, introducing volume exemption for R&D, searching for alternatives by means of the authorization process, and implementing product and process oriented research and development (PPORD). Moreover by introducing transfer mechanisms of industry information through FDS, Registration dossiers, SIEF, the obligation to communicate through the supply chain, REACH has the capacity to stimulate the process of knowledge creation on the development of safe chemicals and practices. It also tends to remove some innovation barriers in the chemical industry by putting an end to the dual-track system between old and new substances, by encouraging joint submissions and by exempting polymers and intermediates.

In order to pull demand toward eco-innovation, REACH runs on the extended responsibility principle and increases the access and scrutiny of information about chemical substances.

The main results of our empirical analysis stress that indeed extended responsibility has a significant positive impact on eco-innovation. On the supply side, the process of authorization plays an important role in triggering eco-innovation. It appears to be the major driver for eco-innovation. We also show that the obligation to transmit information through the supply chain has a positive influence on eco-innovation. This result points out the idea that eco-innovation tend to use more external sources of information and more particularly supplier information.

Though mechanisms of information transfer are able to intensify the capacity of exchanging external knowledge, REACH can be problematic for intellectual property rights. In fact according to the CSES report (2012) some firms are concerned by the ability of REACH to protect the intellectual property and this can represent an obstacle to innovate. Several studies show that the question of private appropriation is of great importance for eco-innovation activities.
Paradoxically eco-innovation use more external sources of knowledge but also need more patent protection. This stresses the necessary trade-offs of regulation between transparency and confidentiality to stimulate eco-innovation.

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Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the regions.


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Reshaping Standard Microeconomics for Political Action: Kenneth J. Arrow and Thomas C. Schelling’s Rand Corporation Projects on Racial Issues

Nabila Arfaoui

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