Eco-innovation and regulatory push/pull effect in the case of REACH regulation: Empirical evidence from survey data

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Abstract: Numerous theoretical and empirical studies demonstrate a positive correlation between eco-innovation and environmental regulation. However, only few analyses explain how environmental policies drive eco-innovation. This paper attempts to fill this gap by studying eco-innovation-friendly mechanisms in the way that the European REACH (Registration, Evaluation, Authorization of Chemicals) regulation has been designed. The aim of REACH, which went into effect 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 analysing the relationship between environmental regulation and eco-innovation. The primary contribution of this paper is the explanation of how regulation encourages eco-innovation. The study uses data from a unique original survey that identifies innovation-friendly mechanisms in relation to the push/pull effect of regulation on environmental innovations. Our results demonstrate the following: (1) The process of authorization and the obligation to transmit information through the supply chain play an important role in "pushing" eco-innovation. This finding stresses the importance for policy makers to promote new "green knowledge" to encourage eco-innovation. (2) Extending responsibility has a significantly positive effect on "pulling" eco-innovation. (3) Only well-designed instruments that are appropriate to the techno-industrial and institutional contexts in which they will be applied lead to innovation.

Keywords: Eco-Innovation, REACH, Regulatory Push/Pull Effect, Econometric Modelling

JEL codes: Q55, Q58, C51

1. INTRODUCTION

The chemical industry plays a prominent role in the management of environmental and health risks through the activities of suppliers in a wide range of industries that produce final and intermediate goods. In particular, any change in the environmental footprint of the chemical sector has an indirect effect on downstream industries. For this reason, the chemical industry is one of the most heavily regulated industries.

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

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 ton 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 that contain 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 that use quantities of more than 10 tons 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 the industry by which firms are responsible for demonstrating the safety of their products. This principle also extends responsibility 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. Therefore, REACH not only applies to the chemical industry but concerns all industries. REACH also introduced an information transfer mechanism through the supply chain. The production and transmission of information is based on the Safety Data Sheets (SDS) and on organizational structures made for sharing and pooling the information within the 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 particularly worrisome, which are called substances of very high concern (SVHC) "with the aim of substituting them".

Under the preamble of regulation no. 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 it has the scope to induce the adoption of eco-innovation as a side effect of the regulation itself. Unlike the previous regulations, REACH does not fit into a traditional approach command or control type; rather, it proposes a unique combination of environmental policy instruments with the aim to stimulate eco-innovation. Therefore, REACH appears to be a privileged and original object of study to analyse the relationship between regulation and eco-innovation.

In the economic literature, many theoretical and empirical studies show a positive correlation between eco-innovation and environmental regulation (Porter and van der Linde, 1995; Lanjouw and Mody, 1996; Jaffe and al., 2003, Horbach, 2008). According to Rennings (2000) regulation is an important determinant that stimulates the "regulatory push/pull" on eco-innovation. However, as underlined by Kemp and Pontoglio, in the exhaustive surveys of relationship between regulation and eco-innovation, "more research should be done on how environmental policies influence the direction of innovation and compliance choices" (2011, p.34). 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. We present the results of an econometric study based on data collected from an original survey on REACH regulation. The objective of the survey is to clearly highlight which innovation-friendly mechanisms attached to REACH may have an effect on eco-innovation and how such mechanisms influence the eco-innovation process. Thus, this paper contributes to a better understanding of the "doubly regulatory effect" (Rennings, 2000) on eco-innovation. The paper is organized as follows. Section 2 presents the main theoretical hypothesis that we will test concerning the effect of REACH upon eco-innovation. Section 3 presents the data and explains the econometric model. Section 4 summarizes the main results, and Section 5 discusses the findings and the policy implications of the study.

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, 2012, Jänicke and Lindemann, 2010). According to Porter and van der Linde (1995), environmental regulation stimulates innovation and improves the competitive position of companies. A strict regulation will, on one side, increase firms' abatement expenditure. On the other side, these additional costs push companies to overhaul their production processes and therefore to innovate. Innovation offsets can lead to a win-win result. Indeed, to ensure compliance with regulation, firms undertake innovative action that not only protect the environment but 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 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 the “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. Another empirical study that provides an interim evaluation of the effect of REACH on the innovativeness of the European chemical industry also stresses 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 through an original combination of environmental policy instruments.

2.1. The regulatory-push effect of REACH regulation

According to Nemet (2009) there are two types of techno-push policy. First, policy affects the size of the market; second, policy directly influences the supply of new knowledge. To “push” eco-innovation, we can observe that 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 to 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 creating 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 they are based on the capacity of firms to develop and to acquire new knowledge (Malerba and Orsenigo, 1996, 1997).

Thus, successful environmental innovation requires new combinations of knowledge and skills about product characteristics, processes, material characteristics and available technologies and markets. The new production system challenges the exiting skills and knowledge of firms, creating high switching costs. According to Horbach et al 2013 (p.537), in environmental innovation, "policy instruments must help firms to overcome knowledge barriers". To enhance the capacity of firms to develop new skills and knowledge in environmental technologies, we consider that environmental regulation to stimulate eco-innovation must create a new « learning space » in environmental technology by developing new sources of internal and external information. REACH seems to fit perfectly into this context because the regulation has led to an increase in the environmental information base of the chemical industry.

REACH tends to stimulate internal sources by supporting R&D activities. In the economic literature, R&D activities are considered an insufficient condition to innovate (Äkerblom, Virtaharju and Leppäahti, 1996; Felder et 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 to create new products and processes. Second, firms that perform R&D are also more willing to use the 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 volume exemption for R&D*. REACH forces firms to register and evaluate all substances produced or used. However, REACH provides an exemption for substances with a quantity of less than one ton per year used in R&D activities. Thus, firms can use substances for scientific experimentation, analysis or research without the obligation of the registration, evaluation and authorization process.
- *PPORD (product and process-oriented research and development)*. The second pro-R&D mechanism is the PPORD, which allows firms to use substances in the scientific research process without registering for 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.

- *Authorization process*. The third mechanism that stimulates R&D activities lies in the authorization process. The aim of the authorization process is to substitute the production and the use of chemicals that are particularly worrisome, i.e., substances of very high concern (SVHC). SVHC are gradually identified by a Member State or the European Commission. They 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 set date unless the company is granted an authorization. The granting or refusal of authorization is based primarily on the existence of economically and technically viable alternatives. Therefore, 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. Therefore, 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 R&D activities. Moreover, authorizations are granted for a period and can be reviewed at any time if new information on possible substitutes is available and economically viable. Firms are thus encouraged to stimulate alternative R&D activities and to maintain a technology watch. According to Arfaoui et al (2013), the process of authorization has been designed to develop R&D activities and to maintain a technology watch on alternative substances.

All these elements suggest the following hypothesis:

Hypothesis 1: REACH tends to encourage eco-innovation by stimulating internal R&D activities.

REACH also tends to stimulate external sources of information by enhancing the capacity of external information exchange with the goal to develop environmental innovation. The interactions between firms and the external environment (i.e., suppliers, competitors, universities and public research) are essential in interdependent and complex innovation processes. The ability to exchange external information is important to overcome incomplete information within a firm, to facilitate the coordination of innovation activities and to enhance their capacity to innovate. This aspect has also been noted by Porter and van der Linde (1995 p.99) 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".

In the chemical industry, the link between internal and external sources of information is particularly important for successful eco-innovation. The skills to develop environmental innovations are often located outside the polluting industry (Kemp, 1997; Cesaroni et al 2009; Kiriyama 2010). 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; De Marchi, 2012; Horbach et al 2013) analyse the issue of information used to eco-innovate. They show that external information positively influences the adoption of eco-innovation and that eco-innovation requires stronger external sources of information.

From this perspective, REACH introduces mechanisms that contribute to an external exchange of information in environmental fields based on:

- *The registration and evaluation dossiers*. Through the process of registration and the evaluation of chemicals, firms are forced to provide all existing data on the properties of the chemicals and on the environmental risks. Without data, companies cannot use the substances: "No data, no market" summarizes ECHA. Therefore, registration and evaluation dossiers must contain a technical dossier with physicochemical, toxicological and eco-toxicological data and a chemical safety report. All information about the substance is available on the ECHA website once the agency has evaluated the dossiers. Consequently, the registration dossiers represent an important external information source that improves the knowledge of the companies on chemicals and their environmental and health risks. By forcing the provision of information, it is expected that this information will bring new knowledge that can stimulate new ideas.

- *The obligation to transmit information through the supply chain*. REACH also implements the obligation to communicate information through the supply chain, which creates new sources of information that are likely to improve the knowledge of suppliers and users. REACH concerns the manufacturer of the substance and the downstream user, who is now responsible for the compliance of the factors of production to the requirements of the new regulation. The goal is to define and evaluate the total environmental load associated with products. Therefore, 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 reports. Downstream users have to communicate about their uses so that suppliers can introduce them in the exposure and risk management measures described in the scenario. With the obligation to communicate information along the supply chain, we can consider that REACH tends to introduce an environmental supply chain management (EMS) 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 the transformation of goods from the extraction of raw materials to the product's end use (Seuring et al 2008). For Greffen and Rothenberg (2000), supply chain management is an important source of information to enhance radical environmental innovation. Supply chain management allows for the coordination of these activities to improve supply chain relationships to achieve a sustainable competitive advantage. According to Kemp (1997), in the environmental field, as contacts between users and suppliers become closer and access to external sources of knowledge improves, innovation becomes more likely. Therefore, by forcing communication in the supply chain, REACH could improve the direction and pace of innovation and the development of environmental products.

- *The SDS* (safety data sheet). The SDS plays an important role in supporting the transmission of information along the supply chain. The regulation provides for the obligation for chemical manufacturers to provide SDS to all downstream users and distributors they supply. Therefore, the SDS promotes exchanges between suppliers and users and is a source of information for the supplier side to clearly identify the uses of his substance and for the downstream user side better understand and manage the risks and dangers associated with its use.
- *The Substance Information Exchange Forum* (SIEFs), or Consortia. 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 that leads to new ideas related to the development of new products or the use of existing substances and the creation of new collaborations.

Thus, we can consider that 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. Given what we have just exposed, we propose the following hypothesis:

Hypothesis 2: REACH enhances the capacity of external information exchange to stimulate eco-innovation

2.1.2. Barriers to innovation and REACH

Environmental innovations imply costly investments and risky returns and create cost barriers that may deter innovative strategies (Kapoor and Oksnes, 2011; Ghisetti et al 2015). Hence, to "push" new technological opportunities for environmental innovation, regulation must reduce the private cost of producing them by removing cost barriers.

In the chemical industry, cost barriers 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.

- *The end of distinction between new and old substance*. First, 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[1]. This distinction between new and old substances creates

[1] The first European environmental regulations appeared in the early 1980s. The objective of these regulations was 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 were identified in the EU, there were 100,106 on the market (Diderich, 2011). The regulations provided that any substance listed in the inventory were considered a new

barriers to the development of radically new substances because it is more costly (Wolf and Delgado 2003). Firms are more willing to create new products from existing substances rooted in the petrochemical paradigm because there was no need to register and evaluate the substance. Since REACH entered into force in 2007, there has no longer been a 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 a lower probability to be considered a hazardous substance and to be prohibited.

- *Joint submission*. Second, REACH implements joint submissions to share the costs and to prevent 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 and evaluation of the substance. Consequently, firms benefit from a reduced registration fee, and they can share the costs of tests.

- *Polymers and intermediates exemption*. Finally, REACH tends to reduce the length of the registration process, which affects the time-to-market of the substance and represents a barrier to innovation. In some markets, such as cosmetics, the time-to-market has a significant effect 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, such as polymers or isolated intermediates, increase the time to market of new substances. Indeed, an article may contain several isolated intermediates or polymers, and the obligation to notify each of them increases the time to market. However, these substances are not considered to be of concern for health or the environment (Nordbeck and Faust 2002; Wolf and Delgado. 2003). Thus, 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

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substance. This should be recorded and evaluated by the industry before being placed on the market. The authorities evaluated existing substances when there was scientific doubt about their harmfulness.

industry and remove one of the main barriers to innovation in this field.

All these elements propose the following hypothesis:

Hypothesis 3: REACH encourages environmental innovation by reducing the cost barrier and market access.

2.2. The regulatory pull effect on REACH regulation

The literature on environmental innovation also stresses the role of demand in eco-innovation. Elkington (1994) shows that the success of environmental strategies is strongly related to the expansion of new classes of consumers. Nevertheless, the demand for eco-innovation is upset by the existence of another type of market failure due to the lack of reliable information on environmental and health quality goods.

The reason for this 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 for consumers to assess, 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 it is 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 regarding the environmental quality of the product they are buying. Akerlof (1970) shows that the presence of asymmetric information between producers and consumers regarding the quality of the product may cause superior products to be "driven out" of the market by inferior products (adverse selection). Consumers are not willing to pay more for products with higher environmental quality and health benefits about which they cannot be certain Rennings (2000). This information asymmetry can represent a barrier to environmental innovation. Thus, Florida (1996), Popp et al. (2007) and Horbach (2008) show that demand for eco-innovation is essentially driven by public pressure. Contrary to classic innovation, in the case of eco-innovation, demand-pull effects are strongly supported by environmental policies.

To “pull” eco-innovation, REACH implements different mechanisms to modify the intrinsic and external motivation of clients toward cleaner products.

- *Increase information*: The first mechanism attempts to increase information related to chemicals. The chemical industry is particularly subject to asymmetric information. Information on the environmental and health effects of chemicals is almost nonexistent. According to the European commission (2009), for nearly 21% of chemicals, there are no data at all, nor are there data for physicochemical properties, the environmental and health risks. Only 3% have been fully tested and for which complete information is available.

For Béal et al (2013) REACH increases the access and scrutiny of information about the environmental and health risks of chemical substances. With the REACH regulation, firms must register and evaluate all substances and post the data in a central database managed by ECHA. This process is extremely important because the aim is to evaluate the intrinsic properties of chemical substances to identify hazards to human health and the environment to communicate this information to the user. This information is accessible to firms, individuals and 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 consider the following hypothesis:

Hypothesis 4: REACH modifies the demand for eco-innovation by increasing the environmental information of clients.

- *Extend responsibility*. The second mechanism to stimulate demand for eco-innovation is the principle of extended responsibility to users. In the chemical industry, innovation is influenced by demand, particularly by supplier-client relationships. In several activities, such as treatment surface activities, supplier-client relationships can be an obstacle to the development and the diffusion of eco-innovation (Belis-Bergouignan et al., 2004). By extending producer responsibility, policies impose responsibility for the product’s end-of-life and encourage producers to change their products and thus to develop eco-innovations (Brouillat et al, 2012; Lindhqvist, 2000). Sustainable economics involves a structural approach to the product life cycle to define and evaluate the total environmental load associated with a product. For Sarkis (2004), the life cycle must be based on the sharing of environmental responsibility to achieve a reduced environmental burden caused by industry.

By extending responsibility, the aim of REACH is to place the environmental effect of the activity throughout the production chain to change the demand of users' downstream chemical products towards more environmentally friendly products (Arfaoui et al, 2013). In accordance with the REACH regulation, downstream users are now responsible for the environmental and health safety of their factors of production. They are closely associated with regulatory compliance by actively supporting the efforts of manufacturers of substances to develop a safe substance.

We thus propose the following hypothesis:
Hypothesis 5: REACH modifies the demand for eco-innovation by extending responsibility through the supply chain.

3. SURVEY DESCRIPTIONS AND REGRESSION MODEL

3.1 Data and descriptive statistics

Both empirical and theoretical literature regarding the effect of REACH on innovation remains scarce because the implementation phase is an on-going process. Moreover, it is difficult to conduct effective assessment studies because of a lack of data. Hence, we conduct our empirical analysis based on a unique survey on REACH administered to chemical firms in the PACA Region (France). A relevant sample was created 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, a questionnaire about REACH was naturally the best way to mobilize their members.

The anonymous survey was conducted online between December 2012 and June 2013. There were 196 usable survey responses. The sample can be considered representative because it represents 32% of the chemical firms in the region (INSEE 2011) and is close to the threshold of one third of respondents, which as generally considered satisfactory. This sample is also representative in terms of firm size because 62,24% are firms that employ 1 to 9 persons (against 65% according INSEE), 22,45% are firms that employ 10 to 49 persons (against 19% according INSEE), 10,20% are firms that employ 50 to 249 persons (against 9% according INSEE) and 5,10% are firms that employ more than 250 persons (against 7% according INSEE).

Moreover, nearly 41.32% of respondents are upstream in the supply chain of chemicals. Indeed, 20.92% are formulators of chemicals, and 20.41% are producers of substances. The end users of chemicals and producers of articles containing substances represent 17.35% and 13.78% of companies. These percentages can be explained by the fact that petrochemicals and parachemicals essentially characterize the chemical industry in the PACA region. These two sub-sectors produce or formulate chemicals and therefore lie upstream of the production process.

Importers of substances or articles containing substances represent only 3.57% of the sample. This is based on the fact that the chemical industry in the PACA region is essentially an export industry that accounts for 30% of regional exports (INSEE, 2011).

	Freq.	Percent	Cum
Size			
1-9	122	62,24	62,24
10-49	44	22,45	84,69
50-249	20	10,20	94,90
>250	10	5,10	100
Activity			
R&D organization	26	13,27	13,27
Formulator	41	20,92	34,19
Manufacturer of chemicals	40	20,41	54,60
Producer of articles that contain chemicals	27	13,78	68,38
Distributor of chemicals	21	10,71	79,09
End user of chemicals	34	17,35	96,44
Importer of articles that contain chemicals	2	1,02	97,46
Importer of chemicals	5	2,55	100
Total	196	100	

Table 1. Description of the sample

3.2 Econometric methodology and variables

The survey aims to analyse the effect of REACH on innovation in the PACA region, particularly in eco-innovation. The definition of eco-innovation used in the survey is inspired by the one applied in the CIS 2010 survey. This definition follows the concept developed in the MEI project (2008), wherein the aspects of the environment and health are introduced. Thus, 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."

In our analysis, we use a probit model (Green, 2008) because 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 $(Y = 1 | x) = F(x, \beta)$. Because of the binary character of our dependent variable, we use the probit model assuming the normal distribution:

Prob $(Y = 1 | x) = \varphi(x' \beta)$. The parameters β reflect the effect of changes in x on the probability (Greene, 2008, p.772).

Table 2 shows the distribution of respondents in terms of whether they have introduced eco-innovations to comply with REACH. We see that 56,12% of firms introduced eco-innovation in response to REACH regulation, and 43, 88% of firms did not.

EI	Freq.	Percent	Cum
0	86	43,88	43,88
1	110	56,12	100
Total	196	100	

Table 2. Distribution of firms that introduced EI or did not

The purpose of the econometric estimations presented in this paper is to study which innovation-friendly mechanisms attached to REACH have an effect on eco-innovation and the extent to which these mechanisms influence eco-innovation.

Following our theoretical considerations and hypotheses on the regulatory push/pull effect, two main sets of variables are distinguished in REACH regulation: those related to regulatory-push mechanisms and those attached to regulatory pull mechanisms.

The first set of variables enables the capturing of R&D activities, information sources and cost and market access barriers. For R&D activities, we consider R&D exemption (RDExp), process-oriented research and development (PPORD) and the process of authorization (Autho). As information sources, we take into account the Registration dossier (R-Dossier), FDS, SIEF, and the supplier (supplierinfo). 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 effect of the joint test (Cross Test), and the effect 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 differences in size and activities within the supply chain of chemicals. Furthermore, 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 (mixers) of chemical substances, 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.

The following econometric analysis tries to empirically assess our theoretically derived main hypotheses. Table 3 summarizes these hypotheses by linking them to our empirical variables.

<table>
<tr><th colspan="2">Regulatory-push mechanisms</th><th colspan="2">Regulatory-pull mechanisms</th></tr>
<tr><th>Hypothesis</th><th>Variables</th><th>Hypothesis</th><th>Variables</th></tr>
<tr><td>H1: REACH encourages eco-innovation by stimulating internal R&D activities.</td><td>RD
RDExp
PRODD
Autho</td><td>H4: REACH modifies the demand toward eco-innovation by increasing environmental information of clients.</td><td>Clientinfo</td></tr>
<tr><td>H2: REACH enhances the capacity of external information exchange to stimulate eco-innovation.</td><td>R-Dossier
FDS
SIEF
supplierinfo,</td><td rowspan="2">H5: REACH modifies the demand for eco-innovation by extending responsibility through the supply chain.</td><td rowspan="2">Extendresp</td></tr>
<tr><td>H3: REACH encourages environmental innovation by reducing the cost barrier and the market access.</td><td>New/Old
Cross Test
Intermed Exp
PolyExp</td></tr>
</table>

Table 3. Empirical assessment of the main hypotheses

4. Results

Table 4 depicts the results of the probit regression fit.

Dependent variable: Eco-innovation in response to REACH
Survey question: “Has the REACH regulation encouraged your company to conduct innovative activities in the field of health and the environment that your company would not have done if the regulation had not been adopted?”
1 if firm developed eco-innovation in response of REACH
0 otherwise

Regression *Probit*			Effect marginal		
Regulatory Push			***Regulatory Push***		
R&D activities			R&D activities		
RDExp	0,60	(0,47)	RDExp	0.27	(0.17)
PRODD	0,69	(0,46)	PRODD	0.12	(0.20)
Autho	1,34	(0,36)***	Autho	0.48	(0.10)***
Information sources			Information sources		
R-Dossier	-0,48	(0,43)	R-Dossier	-0.18	(0.16)
FDS	-0,35	(0,37)	FDS	-0.14	(0.14)
SIEF	0,76	(0,71)	SIEF	0.26	(0.16)
Supplierinfo	1,07	(0,56)**	Supplierinfo	0.36	(0.14)***
Cost barrier and Market access			Cost barrier and Market access		
New/Old	-0,81	(0,47)	New/Old	-0.31	(0.16)
Cross Test	0,54	(0,91)	Cross Test	0.19	(0.28)
Intermed Exp	0,75	(0,54)	Intermed Exp	0.26	(0.16)
PolyExp	-0,32	(0,54)	PolyExp	-0.12	(0.21)
Regulatory Pull			***Regulatory Pull***		
Clientinfo	-0,63	(0,47)	Clientinfo	-0.25	(0.17)
Extendresp	1,11	(0,42)**	Extendresp	0.31	(0.13)***
Control variables			Control variables		
Size 1-9	-0,31	(0,77)	Size 1-9	-0.12	(0.30)
Size 10-49	0,20	(0,69)	Size 10-49	-0.08	(0.27)
Size 50-249	-1,42	(0,75)**	Size 50-249	-0.49	(0.17)
Formulator	0,96	(0,42)**	Formulator	0.33	(0.12)***
R&D organization	0,41	(0,51)	R&D organization	0.15	(0.18)
Manufacturer of Chemicals	1,24	(0,37)***	Manufacturer of Chemicals	0,41	(0.09)***
Producer of articles	-0,58	(0,42)	Producer of articles		
Contains chemicals			Contains chemicals	-0.23	(0.16)

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

Table 4 probit regression

The results of the econometric analysis (see Table 4) show that the process of authorization essentially stimulates eco-innovation. The positive coefficients at the 0.1% significance level of this variable underline a positive regulatory-push effect on R&D activities towards sustainable development and give support for hypothesis H1. Moreover, this mechanism appears to be the major driver of eco-innovation, as indicated by the marginal effect of the corresponding variable, which is the highest one (54%). Nevertheless, concerning R&D, exemption and process-oriented research and development (PPORD) do not appear to have a significant influence on stimulating R&D activities on eco-innovation.

Furthermore, it appears that the obligation to communicate information through the supply chain encourages a technology-push policy effect on eco-innovation. These findings underscore the positive effect of external information on eco-innovation and indicate the importance of the supply chain as external sources of information. Hence, we find clear support for hypothesis H2. However, other external sources of information have no significant effect on eco-innovation. RDossier, FDS and SIEF seem not to be important sources to stimulate eco-innovation.

Regarding variables New/Old, Test, Intermed Exp, PolyExp, the results of the probit model show no statistically significant effect upon the development of eco-innovation. These results suggest that theses mechanisms of REACH regulation do not remove barriers to developing eco-innovation, thereby rejecting hypothesis H3.

As well to the regulatory-pull effect of REACH, the model shows that the coefficient of extended responsibility is positive at the 5% significance level. The result stresses a positive relationship between extended responsibility and eco-innovation. Thus, we can argue that our sample provides empirical to support the theoretical hypothesis that emphasizes that extended responsibility stimulates a positive demand-pull policy effect on eco-innovation. Hypothesis 5 would then be supported. However, the C*lientinfo* variable has no significant effect on eco-innovation. The expected positive effect of the increase in client information on eco-innovation does not seem to occur, thereby rejecting hypothesis H4.

Regarding control variables, the model indicates 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 size, the results show that larger firms have a significant and negative effect on the adoption of eco-innovations and can be explained by the fact that larger firms are considered less flexible and less able to find a market niche (Alcimed 2012).

5. Discussion and Policy Implications

In this section, we discuss how and why our findings demonstrate that certain mechanisms lead to eco-innovation and others do not, before presenting implications from the perspective of policymakers, particularly in the case of REACH regulation.

At first, according to our panel analysis, the authorization process and the obligation to communicate with the supply chain both have a clearly positive effect on eco-innovation. These observations give empirical support to the analysis of Berkhout et al (2003), emphasizing that the process of authorization is the most revolutionary instrument of REACH to encourage eco-innovation because it represents the strongest mechanism to induce research on new substances. Our results are also coherent with the CSES report (2012), which stresses that the authorization process provides a signal regarding the direction for future research activities towards sustainable development. Moreover, our findings confirm previous studies that eco-innovations are influenced by external information, particularly by supply chain information. Several studies, such as Khanna et al. (2009), Rehfeld et al. (2007), Rennings et al. (2006), Wagner (2008) and Horbach (2012), demonstrate that supply chain information is highly correlated with eco-innovation, particularly in the chemical industry. This result can be explained by the fact that communication in the supply chain provides chemical companies with new information about customers and their needs, thereby increasing their capacity to innovate. Thus, from a policy point of view, these findings show the importance stimulating new “green knowledge” to push eco-innovations. However, though mechanisms of information transfer are able to intensify the capacity of exchanging external knowledge, REACH can be problematic for intellectual property rights. Some firms are concerned by the ability of REACH to protect intellectual property, and this can represent an obstacle to innovation (CSES, 2012). Several studies show that the question of private appropriation is of great importance for eco-innovation activities (Horbach et al, 2011). Paradoxically, eco-innovation uses more external sources of knowledge but also needs more patent protection. This stresses the necessary trade-offs of regulation between transparency and confidentiality to stimulate eco-innovation.

Second, the results of this paper indicate also that extend responsibility affect the decision of firms to develop eco-innovation. As shown Lindhqvist (2000) extend producer responsibility creates real economic and legal incentives for the development of cleaner technologies as all producers in the production chain is legally responsible for all environmental damage caused by its product throughout its life cycle. Our result provide support to the theoretical hypothesis consider that extend responsibility stimulate demand-pull effect and encourage firm to design environmental friendly products (Walls, 2006; Fullerton and Wu, 1998; Palmer and Walls, 1999; Brouillat et al., 2012).

Finally, we find no evidence for eco-innovation by the other mechanisms put into place by REACH. In the following, we explore possible explanations of why these mechanisms do not have the expected effect in inducing eco-innovation.

First, concerning the R&D exemption, the volume limit of 1 ton seems to be insufficient to conduct R&D activities in the new substances and products. Furthermore, several firms have explained that they do not use process oriented research and development (PPORD) 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 do not know the condition for the attribution of this authorization. Second, it is expected that the dossier register, FDS and SIEF play a more important role as sources of information for eco-innovation in the last period of registration (2018). In fact, two first-register deadlines (2010 and 2013) concern large volumes of substances whose eco-toxicological properties have been well known (Wolf and Delgado, 2003). Third, for isolated intermediates, the exemption to the restriction of 1 ton per year also seems to be insufficient to have an effect on innovation. According to the Alcimed report (2012), many firms and laboratory applications are often not covered by intermediate exemption. Regarding the exemption of polymers, firms note the problem of the polymer definition. REACH adopts with small volume and less known substances. In a particular definition of a polymer[2] is different from the one used in the chemical industry. Thus, some materials that are commonly called “polymers” or “polymerics”, do not meet the definition of a polymer according to REACH. Moreover, though polymers are exempted from registration, monomers and other reactants used to produce the polymer must be registered. However, the 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 to resolve these formal problems, but it is still not innovative since the final properties are not improved” (CSES, 2012, p.47). In addition, REACH has brought new factors into play that create barriers. Fifth, it seems that the distinction between new and old substances is not clearly removed by REACH. When we analyse Annex VII of the REACH regulation, we observe that in some cases, the difference between existing and new substances still exists. In fact, according to Annex VII, a, b, and c firms that produce new substances between 1-10 t/a systematically have to provide eco-toxicology test data, whereas for “old” substances, firms do not have to unless the substances are likely to cause a risk. Furthermore, the joint submission several SMEs emphasizes the prohibitive price of the letter of access to allow data sharing (Alcimed, 2012). Thus, it would be less expensive for firms to do the tests themselves. Finally, the improving openness and scrutiny of information on chemicals does not seem to have driven the demand towards more environmentally friendly substances because even if more information is available, the information used for chemicals is complex. The user client lacks the scientific knowledge needed to understand all the information, particularly small firms that do not have the appropriate human resources. Moreover, only some fraction of information is made publicly available through the SDSs (including exposure scenarios where applicable) and the ECHA website. Despite being made publicly available, many of the data are still owned by the consortia member companies. Therefore, some ONG emphasize the lack of transparency of ECHA, which refuses to disclose all data.

In summary, it appears that the design of these instruments is not suited to

[2] 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 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 exclusion chromatography (gel permeation).

promote eco-innovation in the chemical industry. Theses results are interesting because they demonstrate that only well-designed instruments lead to eco-innovation. Hence, our study finds empirical support for the studies of Ashford et al., 1985; Hahn, 1989; Johnstone, 2007; Jänicke, 2008, showing that the effectiveness of regulation on eco-innovation depends primarily on the way it is designed and applied. Policy design ends up being essential to the development of eco-innovation. Therefore, policy makers should be attentive in the policy design of regulation and promote instruments appropriate to the techno-industrial and institutional contexts in which regulation will apply (Kemps, 1997) to design efficient regulation in stimulating environmental innovation. Moreover, a number of criteria, such as stringency, timing, credibility and particularly flexibility, are important factors for policy makers to consider. Jänicke (2012) and Johnstone (2007) argue that it is important that the environmental regulation remains flexible to ensure its workability and make it easier to revise strategies and standards to improve its efficiency.

In this respect, REACH regulation promotes open-ended standards and flexible and revisable guidelines every five years (Arfaoui et al 2014). Therefore, it would be appropriate at the next deadline of 2018 to reconsider the volume limit on R&D exemption and isolated intermediates that do not seem to be suited in the chemical industry to promote the development of new product pilots, trials and early production introduction. With regard to process-oriented research and development (PPROD), it would also be appropriate to clearly define the conditions of attribution. Moreover, it would be helpful to ask on about REACH's definition of a polymer, which is different from the one used in the chemical industry and seems create new barriers. Concerning joint submission, policymakers might consider establishing the price of the "letter of access" in terms of the size of the firm for the registration fee. Finally, they should seek to develop new instruments that would increase transparency and popularize chemical data to make them more understandable by the client.

6. Conclusions

This article intends to contribute to a better understanding of the "regulatory push-pull effect" on eco-innovation (Rennings, 2000) based on an original survey on REACH regulation adopted in 2006 with the aim of enhancing eco-innovation. The main contribution of this paper is to bring, from the study of REACH regulation, a new theoretical lens to the field of eco-innovation by showing how design regulation is able to push and pull the environment. We argue that to spur the "regulatory push effect" on eco-innovation, it is pivotal to foster new skills and knowledge in the environmental field by developing instruments that stimulate new sources of internal and external information. Moreover, regulation should remove cost barriers to innovate because environmental innovations imply costly investments and risky returns more than other types of innovation. To stimulate a "regulatory pull effect", it remains important that environmental regulations modify the intrinsic and external motivations of final and intermediate demand toward cleaner products by promoting the available information on the environmental quality of products but also by extending responsibility on the supply chain.

Our study shows that to create "learning spaces" for new environmental knowledge, REACH regulation stimulates R&D activities by 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, and 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. 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 study are as follows: (1) The process of authorization and the obligation to transmit information through the supply chain play an important role in "pushing" eco-innovation. This stresses the importance for policy makers to promote new "green knowledge" to encourage eco-innovation. (2) Extending producer responsibility has a significantly positive "pull" effect on eco-innovation. (3) The other mechanisms put into place by REACH have no effect on eco-innovation because these instruments are not suited to promote eco-innovation in the chemical industry. Hence, our study extends the debate on the role of regulation in eco-innovation by demonstrating that only regulation that is well designed and appropriate for the techno-industrial and institutional contexts in which regulation will be applied leads to innovation. This very first analysis of REACH regulation calls for further research, particularly on how to revise some instruments to improve his effectiveness in inducing eco-innovation.

Appendix Survey question and definition of variable

Survey question	Name of variable	Description
Has the REACH regulation encouraged your company to conduct innovative activities in the field of health and the environment that they would not have done if the regulation had not been adopted?	EI	1 Yes 0 otherwise
Regulatory-push		
R&D activities		
Substances used for purposes of analysis or scientific research, less than 1 tonne per year, are exempt from REACH. Does this exemption lead to increased R & D activities in the field of the environment and health?	RDExp	1 Yes 0 Otherwise
Substances that are manufactured or imported for the purpose of research and development and focus on products and processes (PPORD) are exempted from the registration requirement for a period of five years. (The exemption can be extended on demand.) Does this exemption lead to an intensification of R&D activities in the field of the environment and health?	PRODD	1 Yes 0 otherwise
Following the introduction of new substances to the list of substances subject to authorization, have you performed the R&D activities in the field of the environment and health?	Autho	1 yes 0 Otherwise
Information sources		
Has access to the following sources of information helped stimulate the design and development of products in the field of the environment and health? - Register Dossier - FDS - SIEF	RDossier FDS SIEF	1 Yes 0 Otherwise
Has the obligation to communicate		1 Yes

through the supply chain enhanced your ability to introduce innovations in the field of the environment and health?	Supplierinfo	0 Otherwise
Cost barrier and Market access		
The requirement introduced by the REACH also test the old substances, does has inspired you to develop new less polluting substances?	Newold	1 Yes 0 Otherwise
The possibility to use the tests carried out by third parties results have enhanced your ability to introduce innovations in the field of environment and health?	Cross test	1 Yes 0 Otherwise
Isolated intermediates in quantities less than 1 tonne per year are exempt from REACH. In addition to the requirements for disclosures for an amount greater than 1 ton were reduced compared to the normal procedure. This exemption has stimulated innovation in the field of environment and health?	Intermed Exp	1 Yes 0 Otherwise
The fact that the polymers are exempt from REACH (monomers them are not exempt from REACH) does has helped to stimulate innovation in your company in the field of environment and health?	PolyExp	1 Yes 0 Otherwise
Regulatory-pull		
The increase of the access to environmental risk data on chemical, does stimulate the demand toward environmentally substances?	Clientinfo	1 Yes 0 Otherwise
The extend responsibility adopted by REACH, does stimulate the demand toward environmentally substances?	ExtendRes	1 Yes 0 Otherwise

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