# Credibility of the REACH Regulation: Lessons Drawn from an ABM

Working Paper no 92

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## Work Package 302

## MS216 "Redirecting innovation activities towards ecological targets"

## Working Paper no 92

*This milestone is based on three Working Papers:*

*Find part I "Taxonomy of implemented policy instruments to foster the production of green technologies and improve environmental and economic performance" here.*

*Find part II "Regulatory push-pull effects on innovation: an evaluation of the effects of the REACH regulation on patents in the chemical sector" here.*



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### Abstract

The Europe 2020 Strategy has identified the key goal of smart, more inclusive and sustainable growth. In this direction, redirecting firms' innovation activities towards ecological targets without hampering their competitiveness is of paramount importance.

The double externality issue related to environmental innovations makes the policy intervention crucial in order to avoid sub-optimal commitment of resources to the innovation process and ensure the reduction of polluting agents emissions

However, the positive outcome of any policy inducement mechanisms is not guaranteed, as different policy frameworks may generate different innovative outcomes. An in depth analysis of environmental policy instruments is therefore all the more necessary in order to gain knowledge on the state of the art and evaluate the scenarios for further improvements.

In this perspective, the proposed research project will focus on two main research questions:

1. What are the main existing EU policy instruments explicitly designed to trigger environmental innovations? Which are their main features?

2. Which are the possible avenues leading to successful policy design?

The first research question will be tackled by performing a desk research aiming at analyzing the main environmental regulations introduced in Europe so as to produce a clear and comprehensive taxonomy to shed light on common dimensions and main differences.

The second research question will be addressed by carrying out empirical analyses based on simulation and econometric techniques. We will focus on a specific environmental policy in the chemical domain so as to draw useful insights on the effect of the policy aiming at redirecting innovation activities to environmental targets and also to highlight the main policy best practices.


### Contribution to the Project

The expected output of this project consists of three papers:

1) Taxonomy of implemented policy instruments to foster the production of green technologies and improve environmental and economic performance

2) Agent-based simulation of scenarios of a regulation's impacts on environmental innovations

3) Empirical analysis of the effectiveness of a regulation on the generation of green technologies and on environmental and economic performances

In this respect the research activity is likely to provide a sound contribution to the overall objective of the WWWforEurope project, i.e. is to lay the analytical basis for a socio-ecological transition.

In particular, we will review and classify the state-of-the-art in terms of environmental policy instruments and provide analyses able to identify strengths and weaknesses of a typical regulation explicitly inspired by the Porter hypothesis (i.e. REACh). These are essential steps to identify a feasible European growth and development strategy enabling a socio-ecological transition to high levels of employment, well-being of its citizens, social inclusion, resilience of ecological systems and a significant contribution to the global common goods like climate stability.


## Keywords:

Academic research, Industrial policy, Innovation, Innovation policy, Patents

## Jel codes:

O33, Q53, Q55, Q56, R11

# CREDIBILITY OF THE REACH REGULATION: LESSONS DRAWN FROM AN ABM

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## Working paper

**Abstract.** The present paper takes ground on an agent-based model presented in Arfaoui et al. (2014) to investigate the effects of credibility upon technology substitution such as stimulated by the REACH regulation (EC 1907/2006). The model is used to study how the perceived credibility by clients on the one hand and the perceived credibility by suppliers on the other hand influence or nor the transition from an old established technology to a new safer technology in two opposite scenarios: when the scenario is highly stringent (HS) or weakly stringent (LS) in terms of target-performance and timing. Results show that enhancing client credibility favors technology substitution by accelerating the diffusion of the new environmental technology and benefits the environment. However higher client credibility in the LS has counterproductive effects since suppliers have to face a strong pressure by clients to adopt the new technology but it is not accompanied by a forceful discrimination by public authority. When considering supplier credibility, there is no significant influence except that higher supplier credibility in the LS means stronger pressure to adopt early T2 and to get a mixed portfolio but it turns to be premature since the demand is not ready to buy such a technology. The last section of the paper provides a discussion of these results.

# 1. Introduction

The REACH regulation (EC 1907/2006) is considered to be the most ambitious chemicals legislation in the World[1]. REACH assigns greater responsibility to industry to manage the risks from chemicals and to provide safety information on substances. With respect to a first registration deadline (30 November 2010), European manufacturers and importers had to register the most hazardous chemicals and those produced in the highest volumes. Otherwise they had to stop their use in Europe ("No data, no market"). The second registration deadline in 2013 was for chemicals produced or sold in lower volumes, and the third and last in 2018 for those produced or sold in small volumes. In addition to these deadlines for existing chemicals, companies need to register any new chemical before manufacturing or placing it on the market. In such a context, innovations are enhanced as old and new chemicals are treated equally by REACH. This is important for the competitiveness of the European industry. Industry is also motivated to search for alternatives for those substances or uses that pose the highest risk to man or the environment. The substances of very high concern (SVHC, for example those that cause cancer) are subject to risk management measures, like the obligation to apply for authorization before a substance can be used. From the start, REACH has been designed to balance environmental objectives with competitiveness aims, and has the scope to induce the development and adoption of eco-innovation as a side-effect of the regulation itself. In the economic literature, many authors have emphasized eco-innovations are driven by environmental regulation (Porter and van der Linde, 1995; Rennings, 2000; Jaffe and al., 2003). However, policy design turns to be essential in inducing the development of eco-innovations (Ashford and al., 1985; Hahn, 1989; Johnstone, 2007; Jänicke, 2012). So, the issue of how to design policy in order to stimulate substitution of hazardous chemicals and radical innovation is essential for the effectiveness of REACH. Arfaoui et al. (2014) have attempted to operationalize such policy mechanisms on REACH in a model designed to investigate the co-evolution process between a population of suppliers and a population of clients involved in the transition toward safer alternative solvents. Technology transition can be conceived as a

[1] http://echa.europa.eu/documents/10162/13643/reach_factsheet_worlds_most_ambitious_en.pdf

complex system i.e. one characterized by a tight interrelation between parts and the collective behavior of the system. In order to disentangle such complexity an agent-based methodology proves to be particularly relevant since it explicitly allows investigating specific features of the overall system emerging from the interaction of agents and their behaviors. In this respect, the model allows for a comparison of two opposite scenarios depending upon the degree of severity in terms of required technology performance and upon the timing of regulation: the high stringency scenario and the low-stringency scenario. The low-stringency scenario combines soft targets and late timing while the high stringency scenario combines tight targets and early timing. Results show that substitution that brings radical technological change and significant pollution reduction is possible only if regulation is stringent enough but after many sacrifices, especially in terms of market concentration and number of failures. The model's findings are consistent with the empirical evidence – though rare – on the impact of REACH on innovation such as displayed in the CSES report (2012). In the present work we aim to pursue the formal analysis of policy mechanisms by focusing on the role of credibility. Indeed credibility of policy commitments to future standards is part of the relevant aspects of design and implementation to consider regarding the development of eco-innovation (Kemp and Pontoglio, 2011). Being a complex, ambitious and sequential regulation, credibility of REACH may be a vital element of intertemporal decisions where actors adapt and learn over time. As discussed in the first section, the level of perceived credibility by a firm is important to take into account when assessing the efforts carried out by firms to cope with environmental regulation. In this work we aim to address this very point gaining ground on the ABM developed in Arfaoui et al (2014), investigating how credibility influences technology transition. Section 2 summarizes the model developed in Arfaoui et al. (2014) since we restart from it to analyze the impact of credibility. The simulation allows for an analysis of two credibility parameters: one attached to suppliers and another to clients. Results are displayed in section 3.

## 2. BACKGROUND: CREDIBILITY OF ENVIRONMENTAL REGULATION

This section reviews how the credibility of environmental regulation is studied in the economic literature, especially when considering its capacity to induce the development of new cleaner technologies or eco-innovations. We emphasize that credibility is one aspect among others of the policy design, which matters for supporting eco-innovation. Credibility appears closely related to other dimensions such as stringency, flexibility and timing. The interdependency among these different aspects tends to determine the credibility of a regulation. Moreover some empirical results (OECD data) have stressed the importance of individual perceptions like the perceived stringency of the policy framework to explain the efforts carried out by the agents to comply with an environmental regulation. Following this idea, we use the concept of "perceived credibility" to take into account the individual and subjective sense that may characterize each firm that has to cope with an environmental regulation. We will rely on the REACH regulation to illustrate these concepts.

### 2.1.The ingredients of a credible regulation

Credibility of regulation has been widely analyzed as being related to the issue of public authority commitment. Low credibility of rules is associated with lower rates of investment and growth. When the government is strong, it can commit to secure future investments thus giving private investors the guarantee of a secure market and mitigating the underinvestment effect (Laffont and Tirole 1993: ch. 8). Regarding environmental policy, credible regulatory threats as well as credible and reliable monitoring are essential for a successful implementation. When analyzing voluntary agreements Borkey et al. (1998) have shown that, made at the negotiation stage, a threat of regulation by public authorities provides companies with incentives to go beyond the business as usual trend. As well provisions for monitoring and reporting are essential for keeping track of performance improvements. They constitute the key to avoiding failure to reach targets. Monitoring should be made at both the firm level and the sector level in the case of collective voluntary agreements. In certain contexts, monitoring by independent organizations may be used. Thus credible threats in the form of controls and sanctions must accompany the performance objectives set by the regulator as future targets to achieve by the polluting firms. Some good balance must be found following a "carrot and stick" approach.

Another guarantee of credibility to consider stands in the way policy commitments to future standards are associated with technology policy supporting innovation. This has been underlined by Jaffe et al. (2005) regarding the limited capacity of environmental policies to address the dynamic nature of global environmental problems (like greenhouse gases for instance). In that case, the credibility of policy commitments to future standards is dependent on the willingness of governments to invest resources in improving energy technology to reduce GHG. The difficulty of setting appropriate dynamic environmental policies may warrant more reliance on technology policy, to which governments can commit now (Jaffe et al., 2005, p.169). It follows that coordination between environmental and technology policy will enhance credibility of policy commitments to future standards.

In studies analyzing the role of policy design on eco-innovation (Kemp and Pontoglio, 2011), credibility appears to be one parameter among many others that are relevant aspects of design and implementation (see Box1).

Box 1. Relevant aspects of policy design (Kemp and Pontoglio, 2011):
1. Stringency
2. Predictability
3. Differentiation with regard to industrial sector or the size of the plant
4. Timing: the moment at which they become effective, the use of phase-in periods
5. The credibility of policy commitments to future standards
6. Possibilities for monitoring compliance and discovering noncompliance
7. Enforcement (inspection and penalties for non-compliance)
8. Combination with other instruments of policy

Following this strand of literature, it is essential to consider these various attributes of policy design to induce the development of eco-innovations and to assess the degree to which each attribute is or should be set. However, rather than being independent, these various aspects are interconnected. For instance, stringency is linked with timing which itself is related to flexibility. Stringency means a significant effort to reduce environmental impact or a strong technological jump and both depend on the time frame and horizon given to manage regulatory compliance. Timing and flexibility are also partly related. The moment at which instruments become effective, the use of phase-in periods make the system more or less flexible and inversely greater flexibility will better match particular time frames but will be reduced if firms do not have enough time to adapt. Ashford et al. (1985) underline that "empirical studies report that industry has voiced concern about time allowances that it perceives as too short for extensive development of innovative technologies. One solution would be a flexible delay period to be determined through negotiation between an innovating firm and an EPA technical review panel. The settlement might include periodic monitoring of the firm's progress and noncompliance penalties to alleviate any cost advantage realized as a result of noncompliance" (p.458).

These aspects can have a self-reinforcing action on the credibility characteristic but they can also play the other way round. Expectations play a crucial role in influencing investor behavior and establishing credibility takes time. Too stringent a regulation may be pernicious and weaken its credibility. As highlighted by Ashford et al. (1985), "care must be taken not to design and enforce standards so stringently that the regulated industry perceives that massive noncompliance will result. In that case, the perception of massive noncompliance may serve as a disincentive to innovate since widespread noncompliance could result in an amendment of the compliance deadlines". (p.458). Thus too high stringency may lead to low credibility. As well too flexible a regulation may have counterproductive effects thus negatively affecting its credibility. Looking at carbon policy, Brunner et al. (2011) state that having a flexible policy allows governments to pursue time inconsistent strategies against firms, but firms can also try to exploit regulatory discretion to their own advantage. So-called 'ratchet effects' can occur if firms' current performance is used as a criterion for setting future policy targets (Weitzman, 1980). Brunner et al. (2011) give the example of the periodic update of emission caps in the EU Emissions Trading Scheme (EU ETS). Flexible caps provide firms with an incentive to distort investment decisions in order to signal high compliance costs and prepare the ground for a more lenient cap in subsequent trading periods (Harstad and Eskeland, 2010). A firm's chance of winning with this strategy increases with its market power thus carrying the risk of a regulatory capture.

Finally all these ingredients contribute to get a regulation more or less credible[2]. But what also needs to be taken into account is the subjective perception that firms may foster when coping with some complex and evolving regulation such as REACH. In their empirical study (www.oecd.org/env/cpe/firms), Johnstone et al. (2007) have included data on perceived stringency of the policy framework, number of inspections in the last three years, perceived relative importance of different policy instruments, and the reported presence of targeted measures to encourage the use of environmental management systems or tools. In addition, respondents were requested to report on their perception of the relative importance of a variety of non-governmental stakeholders in influencing environmental practices. They show that "there is very wide variation in the perceived stringency of the environmental policy regime. These may not reflect the actual relative stringency of policy regimes prevailing in different countries, but give a good indication of the perception of their relative stringency. In many of the analyses undertaken, perceived policy stringency is the most important determinant of private environmental performance and innovation…" (Johnstone et al, 2007, p.8). In the following, we propose to consider the "perceived credibility" by the agents in order to take into account such subjectivity as to the capacity of the regulation to be influential. It is consistent with Brunner et al. (2011) who underline that the assessment by firms does not entail a binary choice

[2] Theoretical works (Segerson and Micelli, 1997; Schmelzer, 1997) have clearly established that the level of ambition of negotiated agreements' targets is positively correlated to the degree of credibility of the regulator's threat and to the environmental stringency of the threat.

but rather extends along a continuum between perfectly credible and perfectly incredible. Then the level of perceived credibility by a firm depends on the government's observable incentives[3].

### 2.2. Is REACH credible for inducing innovation?

Table 1 summarizes the characteristics of REACH regarding three main aspects of policy design: stringency, flexibility and pragmatism. Regarding stringency, three complementary mechanisms are used in REACH: legal obligations, sanctions and control. Four main categories of obligations exist through registration and evaluation, authorization and restrictions of certain dangerous substances, information to the supply chain and responsibility of downstream users. The types of offences for the infringement of REACH provisions across Member States, *i.e.*, whether criminal or administrative, vary from one country to another. However most of the countries are enforcing REACH at the administrative level or combine administrative and criminal approaches[4] (Milieu report, 2010). With regards to administrative measures, the main type of sanction is economic (fines). With regards to criminal sanctions, three main types of measures – pecuniary (fines), deprivation of rights (prison sentences) and prohibitions and orders - can be identified. Controls and inspections are carried out by the competent authorities (for instance, inspectors from different competent institutions in France) to assess whether any REACH obligations have been infringed. Especially competent authorities have to control the companies' activity with regard to the most dangerous substances, but also to ensure that endangerment of health and/or the environment have or will not occur.

Empirical data to check the correlation if not the causality of REACH upon innovation are lacking, essentially because it is an on-going

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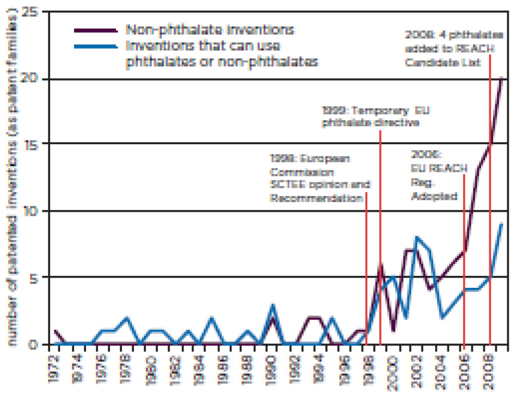
[3] According to Forder (2001) two main factors determine the level of incentives and perceived credibility: reputation and commitment devices.

[4] Countries with a combined approach have usually inserted an element of intentional infringement or of endangerment to justify the use of criminal sanctions (Milieu report, 2010, p.7).

process (CSES, 2012) and radical innovations take time to materialize. However a recent study carried out by the Center for International Environmental Law (CIEL, 2013) examined the impact of laws governing hazardous chemicals in terms of their effect on innovation. It finds that the prospect of stricter laws with regard to toxic chemicals sparked the invention, development, and adoption of alternatives, as it is illustrated in the case of phthalates, a class of chemicals with endocrine disrupting properties. Figure 1 shows the correlation between spikes in the patenting of phthalate-alternatives and the timing of new laws to protect health and environment from phthalates. As the stringency of measures increased, so too did the number of inventions disclosed in patent filings by the chemical industry. Figure 1 particularly shows the significant rise in patented inventions free of hazardous phthalates after the adoption of REACH in 2006 and the subsequent addition of four phthalates in the Candidate list in 2008 submitting those substances to the authorization procedure. In that case of phthalates, REACH appears to be enough stringent to spur radical innovation.

Figure 1: Spike in patented inventions free of hazardous phthalates (source: CIEL, 2013)




Exponential growth in the number of patented inventions for phthalate alternatives beginning in 1999, coinciding with the adoption of stricter rules (as captured by the number of patent families for "non-phthalate" and "phthalate free" inventions).

Flexibility of REACH appears through the periodic update of guidelines, through the means but also through the opening to stakeholders. From the start, it was considered important that the system remain flexible in order to ensure its workability (Fuchs, 2011). Thus REACH is characterized by open-ended standards, flexible and revisable guidelines, and other forms of "soft law". Flexibility and timing are thus closely related to give higher visibility for planning investments. Moreover, REACH promotes a mode of governance based on the idea of "self-responsibility." This approach involves giving more responsibilities to companies and more flexibility on how to achieve the goals (Fuchs, 2011). Finally flexibility stands in the possibility for actors from civil society to participate to the regulation. In relation with innovation, flexibility of REACH allows higher adaptability to diversity, tolerates alternative approaches to problem solving, and makes it easier to revise strategies and standards in light of evolving knowledge (Scott and Trubek, 2002).

As to pragmatism, Fuchs (2011) describes REACH as a pragmatic regulation that is both ambitious and realistic in its goals in order to represent a real incentive to undertake innovation. Pragmatism is also shown in other provisions, such as the multiple deadlines for phase-in substances, the collective setting of priorities under the authorization and restriction processes, the various exemptions incorporated in the regulation, and the limited risk assessment requirements for substances placed on the market in proportions of less than 10 tons. The search for a compromise between ambitious and realistic goals permeates the whole regulation especially when considering the issue of substituting dangerous substances. In particular, the granting or refusal of authorization is based on the existence of economically and technically viable alternatives. It results that such a conditioned decision may delay the search for new safer alternatives. Pragmatism is thus more likely to induce incremental innovations rather than radical innovations.

| Stringency | Flexibility | Pragmatism |
|---|---|---|
| Legal obligations:<br>- Registration and evaluation of substances more than 1 ton<br>- Authorization for SVHC | Inter-temporal flexibility (timing):<br>- Revisable guidelines every 5 years<br>- Timelines for registration and authorization | Ambitious environmental and health goals:<br>- Better knowledge of the risks of existing and new chemical substances<br>- Substitution of SVHC |
| Sanctions:<br>- Administrative: "no data no market"<br>- Legal: 2-year prison sentence, fine of 75 000€ | Means:<br>- Reversal of the burden of proof<br>- Extended responsibility<br>- Learning by doing based on good practice guidance | Realistic economic goals:<br>- Information and cost sharing (consortiums)<br>- Exemptions<br>- Granting or refusal of authorization based on the existence of economically and technically viable alternatives |
| Control:<br>- ECHA<br>- Risk assessment Committee<br>- Committee for Socio-economical Analysis | Open to stakeholders:<br>- Possible interactions with NGOs and public authority through forums (SIEF)<br>- Public consultations | |

Perceived credibility

**Table 1. Characteristics of the REACH policy design**

In sum REACH incorporates crucial attributes of policy design that are able to induce innovation. The extent to which they are set is then also important to consider and may determine the relative credibility of the regulation if we consider the perceived credibility as a combination of stringency/flexibility/pragmatism. We argue that these attributes offer margins for action and possibility for public authorities to adjust their policy through time according to the evolution of technology and accumulation of knowledge.

The objective of the paper is to better understand through an ABM how the perceived credibility of regulation does impact firms' trajectories and favor or disfavor their ability to develop alternative substances such as required by REACH.

## 3. The modeling of the impact of REACH upon technology transition

We cannot provide here a full account of the model. The reader is referred to Arfaoui et al. (2014) for a complete presentation of the formal model and for the details.

### 2.1. The main principles of the model

The model developed in Arfaoui et al. (2014) captures the dynamics of supplier-user relationships in the chemical industry and the development of alternative solvents as they compete and respond to regulatory pressures. Formally we consider two interacting populations of firms, suppliers and clients, and two types of product-related technology: a conventional technology T1 (organic solvents) and a green technology T2 (biosolvents). Suppliers search for dominant position in the market through innovation while clients pursue the objective of finding the most satisfying product consistent with their preferences and with their techno-economic constraints (budget constraint and minimum quality requirement).

Each product-related technology is characterized by a bundle of four attributes: technical performance, production costs, volatile organic compounds (VOCs) emissions and biodegradability. These are critical attributes at stake for solvents in the chemical industry. However solvents and biosolvents do not exhibit the same performance regarding each attribute. That's why in the model T1 and T2 differ in terms of initial values and potential of improvement assigned to each attribute[5]. More specifically T2 being an emergent technology is more expensive and less performing in terms of technical quality than T1 but it is characterized by a greater potential of improvement related to environmental characteristics (VOC and Bio). Only T1 is available at the start of the simulation and sooner or later T2 may be introduced in the market.

Suppliers decide about which technology they adopt or abandon and which product characteristics need to be improved. Regarding the first decision, each supplier examines the possibility of changing its technology portfolio. First the firm has to decide whether T2 is worth to be adopted. It will depend on the cumulated stock of knowledge on T2 and the extent of diffusion of T2 in the market but also on the ability of the firm to pay the switching costs. Second the firm has to decide whether it is worth abandoning T1 based on the share hold by T2 in its total turnover. In the end, three portfolios are possible: T1 only, T2 only or both T1 and T2. As to the second decision, thanks to R&D activities, each firm is able to improve its technology performance (if the portfolio is only T2 or T1+T2) or to accumulate knowledge on T2 (if the portfolio is only T1). The innovation process is firm-specific, uncertain and contingent to the distance to the technological frontier.

Suppliers with a negative budget exit the market and are automatically replaced by new entrants so that the number of firms in the industry remains constant. New entrants imitate established firms with more or less success.

Clients buy one product at each time period and they have the choice between T1 and T2. Thus their decision first consists in selecting which product they will purchase. They do so by taking into account their own preferences for the product characteristics but also by considering their own financial limits (reserve price) and technical quality requirements

[5] Empirical data are used to set initial values of the four product characteristics and the frontiers of the technological potential.

(quality reserve). Second they decide whether to switch to another supplier in case where they are not satisfied in conformity with their preferences and by gauging the current supplier performance with the best industry performance.

From the dynamic interplay between suppliers and clients industry dynamics and technology progress emerge. It is thus possible to examine whether technology transition to technology T2 occurs or not and what are the main emergent properties in terms of T1 and T2's market shares, industry concentration, evolution of the VOC stock and failures likely to turn out. Batches of simulation are generated in order to process stochasticity and to exhibit the main regularities of the dynamics.

The baseline simulations serve as a benchmark to therefore analyze the impact of regulation upon the dynamics. Two policy mechanisms are formally modeled in accordance with the ones underlying REACH: the authorization procedure and the extended producer responsibility. The authorization procedure concerns dangerous substances that need a permit before being used in the market. The permit is authorized for a certain time period only if no economically and technically viable alternatives exist *and* if the firm proves to carry out research activities on alternatives. Otherwise the permit is not granted and the dangerous substance is prohibited after the so called sunset date. In sum, authorization takes place sequentially and involves revisable guidelines in order to force the search for viable alternatives through R&D efforts. In the model, we specify techno-economic performance targets that serve as screening devices in the hand of the public agency (ECHA) to check whether alternative substances exist and if so to ban T1 after the cutoff date. In the contrary case, T1 is allowed until the next review date and a similar sequential checking is taking place. Thus timing is used as second action leverage in the hand of the public agency.

As to the extended producer responsibility, the aim is to get actors in the whole production chain to take into account the environmental impact of the activity and to change the demand of downstream users toward safer substances. Given that, we grasp the extended responsibility affecting the demand of downstream users in the model by representing clients who give more weight to the suppliers' technology portfolio – especially valuing more those with technology T2 in their portfolio – and to the timing of regulation (sunset date and revision date).

Credibility plays a role at three places, one at the supplier level and two at the client level. At the supplier level, the higher the credibility given to regulation, the higher the incentive to adopt T2. At the client level, the higher the credibility given to regulation, the lower the score allocated to suppliers for whom the portfolio is only T1 on the one hand, and the higher the likelihood to make defection in that case on the other hand.

Figure 1 summarizes the main building blocks operating in the model, showing interactions between supply and demand but also between regulation and the various industry entities (supply, demand and industry).

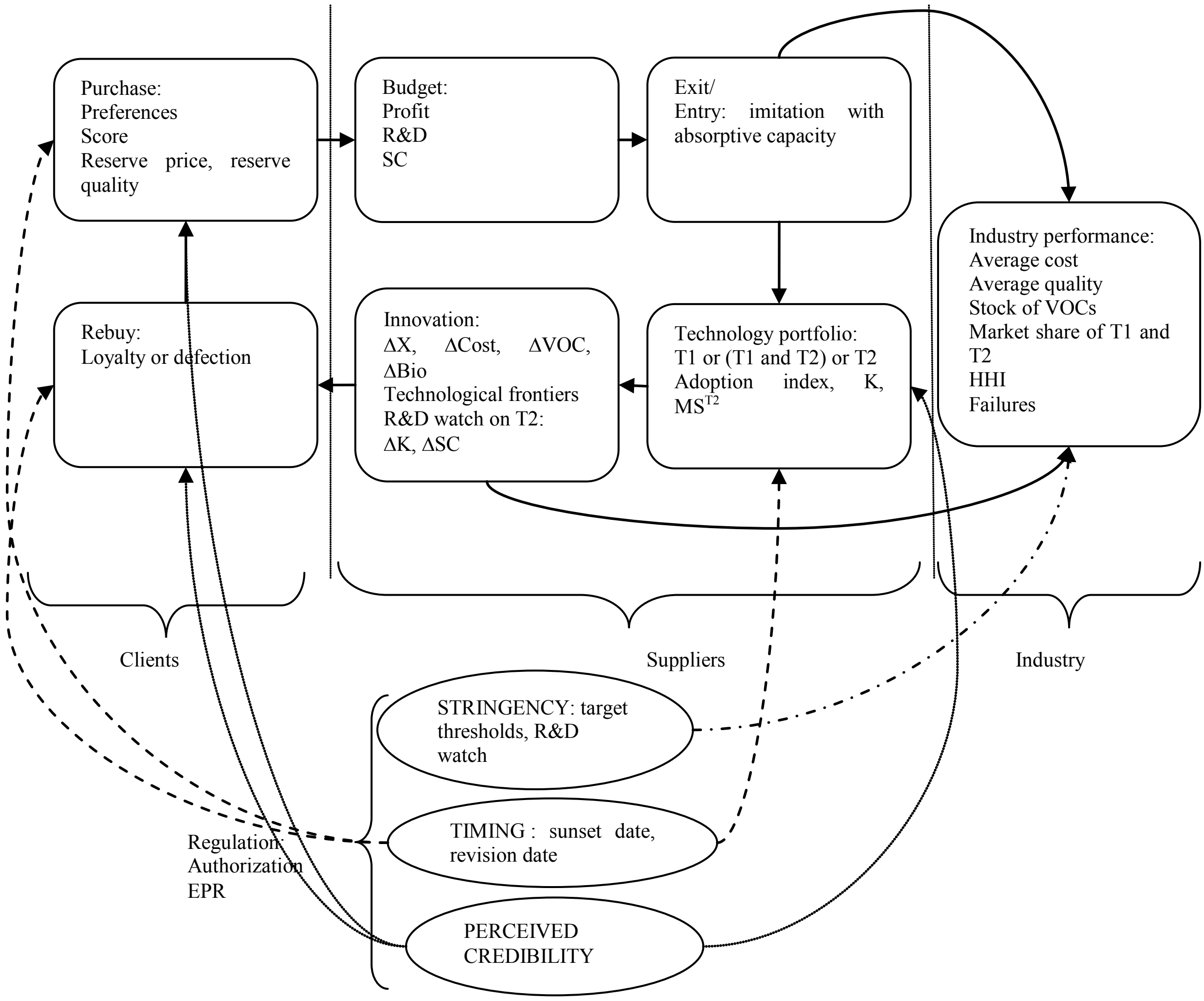



**Fig. 1. Overview of the main building blocks in the Arfaoui et al. model (2014)**

Only the impact of stringency and timing have been tested in Arfaoui et al. (2014) leaving the influence of the perceived credibility for a future work. The aim of this article is to focus on the effects of credibility on technology substitution.

### 3.1.Summary of the results in the Arfaoui et al. (2014) ABM

In Arfaoui et al. (2014) the benchmark configuration is consistent with the main stylized facts of technological change. When considering regulation, two opposite configurations are examined: the low-stringency scenario and the high-stringency scenario.

Only the most stringent scenario allows domination of T2 due to an early ban of T1, whereas the less stringent scenario is characterized by the coexistence of T1 and T2 but still in great favor of T1. Thus technology substitution from T1 to T2 does happen when regulation is very stringent resulting in a significant reduction of environmental impact in the form of a reduction of the VOC stock. However the effective ban of T1 goes with a great number of failures in the industry since every firm still having T1 in their portfolio cannot use the technology anymore after the cutoff date. In turn green pioneers specialized on T2 are rewarded of their risky attitude and can go on capitalizing on the green technology. Progress on T2 is thus early and rapid. Moreover the radical selection of T2 resulting from the early ban of T1 brings a reduction in the market size due to unsatisfied demand regarding the new technology which turns to be expensive and of low quality at the cutoff moment. Again the reduction in the market size contributes to an increase in firms' exit and thus in the number of failures. In total industry concentration increases and distribution of market shares appears significantly unbalanced.

On the contrary, when regulation is soft, T1 is never prohibited and firms specialized in T1 maintain a permanent advantage compared with firms having T2 in their portfolio even if they are disturbed by a regulatory threat during the whole time period. This situation explains why the number of failures is rather low in that configuration but also why the reduction of the VOC stock is slow to come and materialize. In fact, regulation fails to promote technology transition from T1 to T2 because the blade never falls leaving clients with the possibility to purchase T1 till the end but never forcing them to reconsider their willingness to pay for T2 and their quality requirements. Thus firms with T1 never experience a decrease in market size even though they are subject to a check on their R&D watch and through this monitoring way are forced to exit the market. The global result in terms of failures and market concentration is yet within what can be observed in the high stringency scenario. In total product improvements on T1 are continuous whereas progress on T2 is small and delayed. The failure to ban T1 because of lenient performance targets and late timing inhibits further development of T2.

Given these results, we can further explore the impact of credibility on technology transition from T1 to T2.

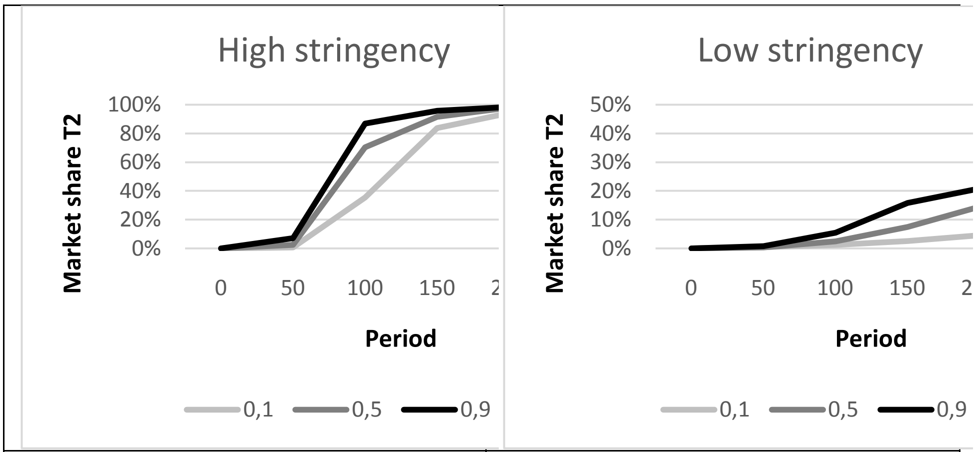
## 4. The effects of credibility in the model

The ABM model we have built enables us to take into account the perceived credibility of the regulation by a firm - one specific to suppliers ($\alpha_i^R$) and one specific to clients ($\alpha_j^R$)- on the one hand and the variation in the perceived credibility on the other hand. We assume that the assessment by firms extends along a continuum between perfectly incredible ($\alpha^R$=0) and perfectly credible ($\alpha^R$=1). We first study the impact of a higher credibility on the client side. We then analyze its impact on the supplier side.

### 3.1 On the client side

As said before, credibility plays at two places at the client level: purchase and product replacement (rebuy). Higher credibility induces clients to less value products coming from suppliers with a portfolio exclusively dedicated to T1. So this link operates when a client has to decide which product to buy and when the client has to decide whether to keep or leave the current supplier.

Figures below depict the evolution of T2's market share (average for 200 simulations) according to different values of the credibility parameter ($\alpha_j^R$) in each scenario (High and Low stringency).




(a) (b)

Fig. 2. Evolution of T2 market share (average for 200 simulations) for different values of client credibility

We observe that for both scenarios (High and Low) the higher clients give credibility to the regulation the higher is the development of T2 in terms of market share. In the High scenario technology transition and the ban of T1 occur at a faster pace because credibility operates on the tempo of T2's development and diffusion. In the Low scenario the boost of T2 takes also place allowing a maximum of 25% market share for T2 in the high credibility case (0.9) even though complete technological substitution (from T1 to T2) still does not happen at the end of the simulation period. In that case credibility tends to modify the sequence of technology adoption rather than its pace.

Regarding the evolution of the global stock of VOCs, we observe that, whatever the scenario (High or Low), higher client credibility leads to a decrease in VOC emissions (data collected at the last period t=250, see Fig. 4) resulting from the greater development and diffusion of T2. Still the gap observed between the two scenarios in favor of the stringent one remains for each value of the credibility parameter.

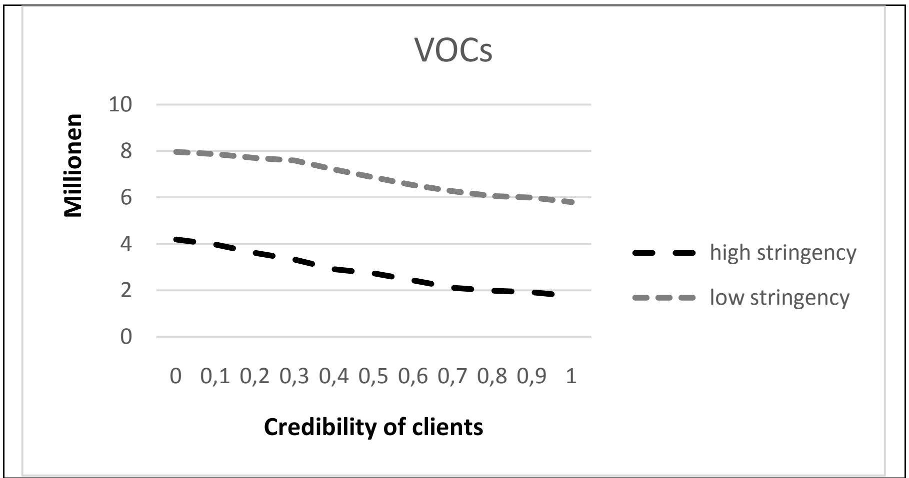
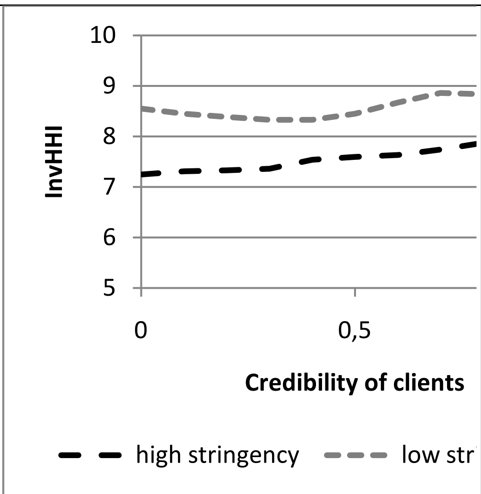
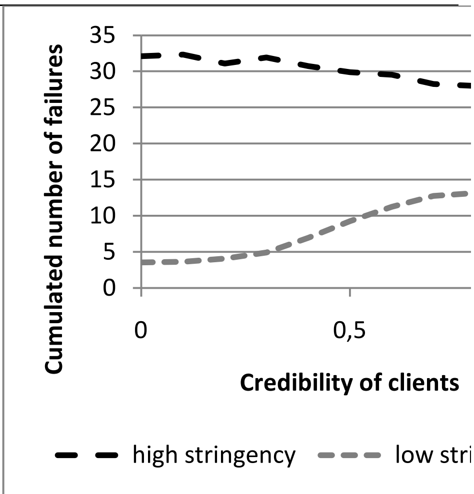



Fig. 3. VOC stock (average for 200 simulations) at t=250 according to different values of client credibility

In total enhancing client credibility favors technology substitution by accelerating the diffusion of T2 and benefits the environment.

If we look at economic effects of an increased credibility of clients, we observe no significant effect on industry concentration (see Fig. 4) whereas the cumulated number of failures is significantly affected showing contrary evolution according to the type of scenario, high or low (see Fig.5). Indeed in the High scenario increased client credibility goes with a decrease in the cumulated number of failures whereas in the Low scenario higher client credibility is associated with an increase in the cumulated number of failures. In fact as said before only the HS brings a ban of T1 and this means both an exit of firms specialized on T1 and a reduction of the market size due to a temporarily unsatisfied demand. In that case higher client credibility pushes firms to bet on T2 from the start, thus leading to higher performance of the substitution technology when the prohibition of T1 is effective. Pioneering environmental firms are rewarded by this double effect of higher client credibility and early ban such that win-win effects are effective. Higher performance of T2 when T1 is banned also goes with lower reduction of the market size and thus lower exits. This explains why in spite of a high level of failures in the HS compared to the LS this level decreases with client credibility.

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|---|---|
| Fig. 4. Inverse HHI (average for 200 simulations) at t=250 for different values of client credibility | Fig. 5. Cumulated number of failures (average for 200 simulations) at t=250 for different values of client credibility |

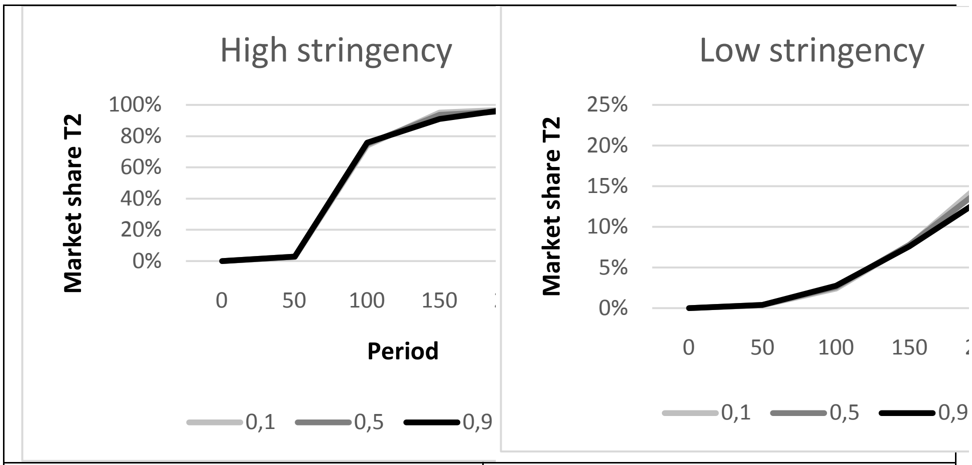
Quite surprisingly in the LS higher client credibility leads to higher number of failures. This is due to the fact that higher client credibility pushes firms to take more risks by adopting earlier T2; but these efforts do not match the corresponding demand since clients go on buying T1 which succeeds in satisfying their techno-economic constraints. The non occurrence of the T1 ban due to a lenient regulation leaves the choice between T1 and T2 to the clients. When credibility is high, client pressure is high but firms adopting T2 are not rewarded by the corresponding sales (pioneering firms are penalized and no win-win effects are possible) and are forced to exit the market thus leading to increased failures. Higher credibility in the LS has thus counterproductive effects.

In sum when the regulation is very stringent the more clients find it credible the faster is the technology transition and the more efficient is the extended producer responsibility. On the contrary when regulation is weak, the more clients find it credible the higher is the pressure put on suppliers to develop T2 who have not enough corresponding demand. This shows the high industry turnover of firms that are not able to capitalize on T2 because client pressure is disconnected with the effective demand still focused on T1. In that case the extended producer responsibility proves to be less efficient.

### 3.2 On the supplier side

Here credibility plays when suppliers have to decide whether they adopt or not the new technology T2. Higher credibility gives more weight to the timing of regulation, thus inducing the firm to adopt T2 more rapidly.

Figures 6a and 6b display for each scenario (High and Low) the evolution of T2's market share when the credibility parameter attached to each supplier varies ($\alpha_i^R$).




(a) (b)

Fig. 6. Evolution of T2 market share (average for 200 simulations) for different values of supplier credibility

In the High scenario, we observe that credibility has no effect on the development of T2 (see Fig. 6a) while surprisingly in the Low scenario credibility turns to negatively influence it (see Fig. 6b). After checking for the significativeness of the values obtained at the last period (t-test[6]), the difference appears to be significant when comparing both extreme cases ($\alpha_i^R$=0.1 *vs* $\alpha_i^R$=0.9). By changing the sequence of T2 adoption, higher supplier credibility means stronger pressure to adopt early T2 and to get a mixed portfolio (T1 and T2) but it turns to be premature since the demand is not ready to buy such a technology. As suppliers are forced to adopt T2 whereas T2 is not sufficiently established, failures tend to increase and exits give place to new entrants that are not able to consistently develop T2 since there is no successful firm with T2 to potentially imitate. In the end, higher supplier credibility hampers the accumulation of knowledge on T2 and has a counterproductive effect on its diffusion.

Concerning the evolution of the stock of VOCs (see Fig. 7), there is no significant effect resulting from a higher supplier credibility.

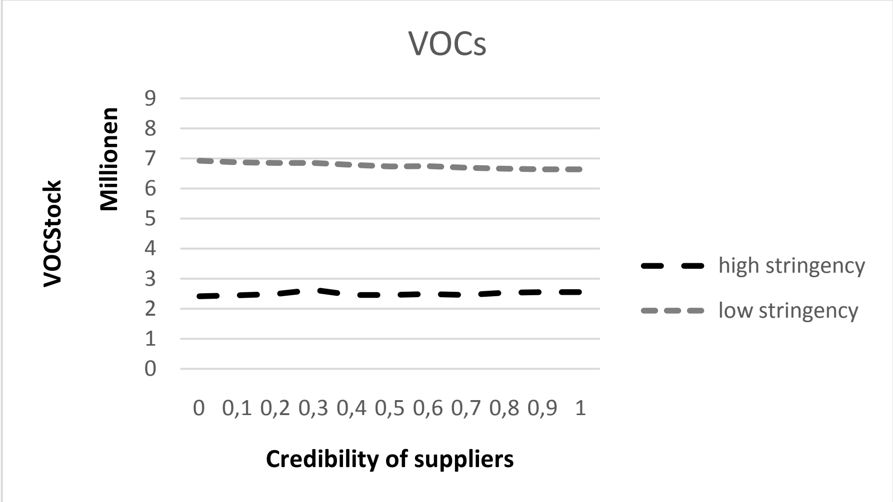
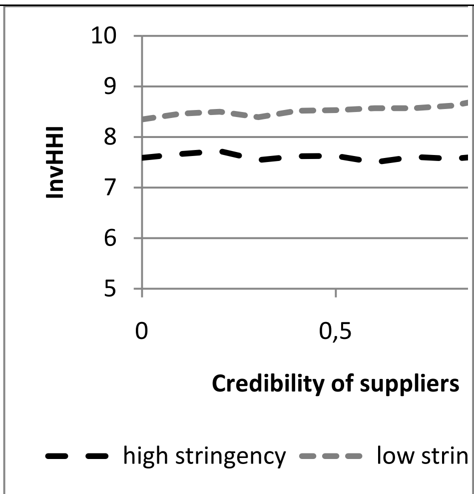


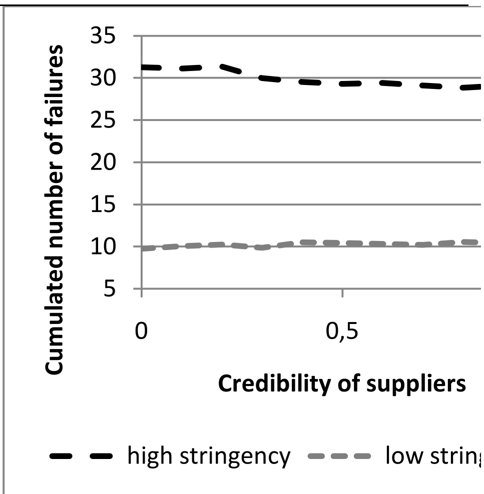

Fig. 7. VOC stock (average for 200 simulations) at t=250 according to different values of supplier credibility

[6] When comparing the case 0.1/0.9, we find a p-value=0.06%***; for the case 0.1/0.5, p-value=12.83%; for the case 0.5/0.9, p-value=3.19%*.

In total, higher supplier credibility has no significant additional effect in the High scenario whereas it produces a negative effect on the development of T2 in the Low scenario though without modifying the global stock of VOC emissions.

When considering the economic effects of higher supplier credibility, we see the absence of significant impact upon industry concentration (see Fig. 8) and upon the cumulated number of failures (see Fig. 9) whatever the scenario. Supplier credibility is economically neutral in our model.




| Fig. 8. Inverse HHI (average for 200 simulations) at t=250 for different values of supplier credibility | Fig. 9. Cumulated number of failures (average for 200 simulations) at t=250 for different values of supplier credibility |
|---|---|

### 3.3 Discussion

As mentioned above, the ABM model provides a way of investigating the effect of credibility upon technology transition in two different regulation scenarios (High and Low stringency). Results are summarized in Fig. 10.

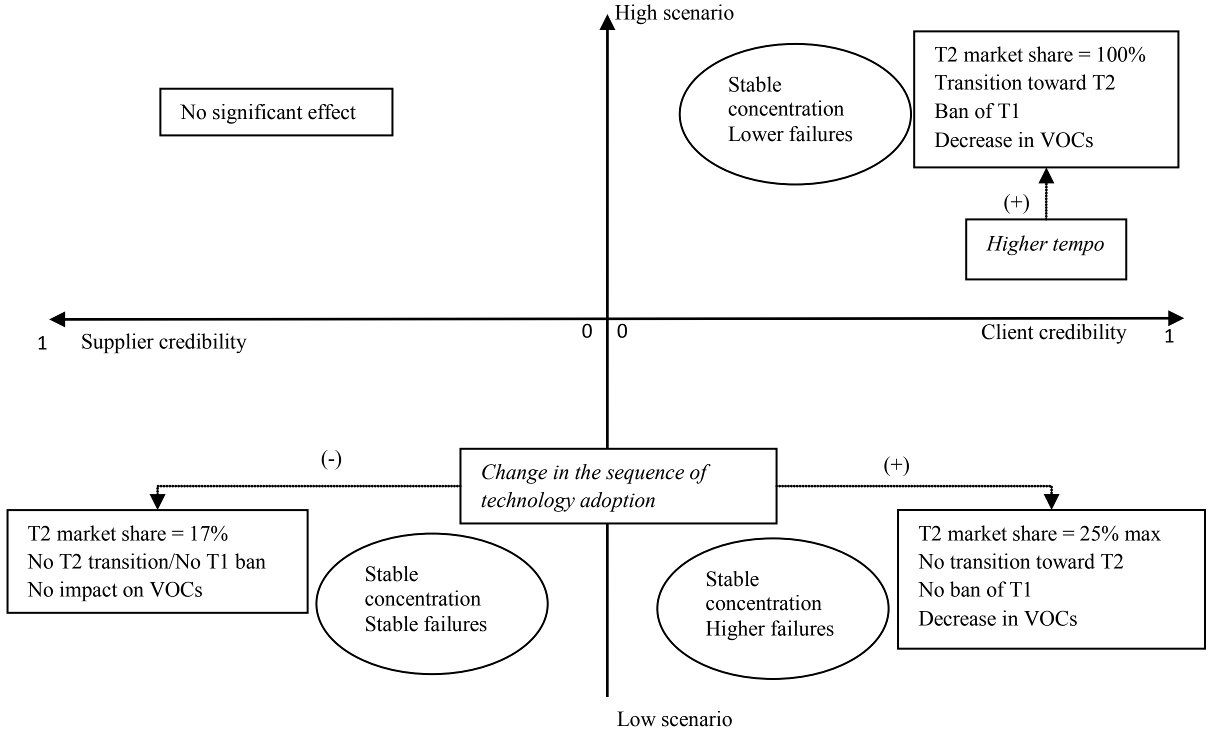



**Fig. 10. Summary of the results**

Our results first prove that the effect of credibility vary according to the type of actor in the value chain. Client credibility is more influential than supplier credibility. This is due to the way we have incorporated credibility in our model in order to mimic the mechanism of extended producer responsibility underlying REACH. Supplier credibility appears only once (adoption decision) whereas client credibility is influential two times (purchase and rebuy).

Second when the regulation is very stringent the more clients find it credible the faster is the technology transition and the more efficient is the extended producer responsibility. On the contrary when regulation is weak, the more clients find it credible the higher is the pressure put on suppliers to develop the new technology. But suppliers have to face a contradictory injunction: strong pressure from clients to make them adopt T2 but weak regulatory incentive to ban T1, thus maintaining competition between the old and new technology. In the end there is a mismatch between supply and demand since the risky attitudes adopted by suppliers with T2 confront a continuous demand on the conventional technology T1. In that case the extended producer responsibility proves to be less efficient.

Finally, in a context of weak regulation, higher supplier credibility leads to counterproductive effects. Indeed firms are induced to untimely adopt the new technology while they have to cope with soft targets and distant timing.

What are the policy implications?

- On the supplier side, what matters is the learning time and experience on T2: need to support accumulation of knowledge on T2 and to protect the market niche for a while from the competition with the old technology;
- EPR is efficient only if suppliers and clients keep in step; it is thus essential to allow knowledge sharing along the value chain;
- On the client side, it is important to build a strong reputation to the agency ECHA and to improve commitment devices toward downstream users through information transparency or labels.

## Conclusion

The present work proceeds with the analysis of policy design upon the development of eco-innovation based on ABMs, especially to disentangle how different aspects of the policy design play on technology transition. Stringency and timing have been examined in Arfaoui et al. (2014). The present paper complements the analysis by examining the effect of credibility. The main result suggests that if the regulation is highly credible for clients it must then be very stringent.

Supplier credibility seems to not play a significant role in the transition dynamics.

This exercise allows to stress that credibility is able to change the tempo as well as the sequence of priority to adopt the new technology. These aspects are relevant dimensions of timing such as described by Adam (2008) and may enrich the analysis of the policy design to support eco-innovation. The paper is also a step toward the better taking into account of the interdependence between the dimensions of the policy design.

These considerations suggest two directions of research. First to better take into account the credibility parameter at the supplier side especially when redirecting R&D. The intuition is that the more credible is the regulation for suppliers the more they will be induced to re-orient their R&D activities toward T2. Second, to make the credibility parameter endogenous and dependent upon other policy design aspects. Especially credibility would depend on stringency but according to an inverse U-shape curve in order to account for the situations where credibility increases with stringency but reaching a certain threshold the inverse relationship would prevail and credibility would decrease with stringency, thus illustrating situations where firms sense that nobody would succeed in coping with the tight regulation.

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# Project Information

## Welfare, Wealth and Work for Europe

## A European research consortium is working on the analytical foundations for a socio-ecological transition

### Abstract

Europe needs change. The financial crisis has exposed long-neglected deficiencies in the present growth path, most visibly in the areas of unemployment and public debt. At the same time, Europe has to cope with new challenges, ranging from globalisation and demographic shifts to new technologies and ecological challenges. Under the title of Welfare, Wealth and Work for Europe – WWWforEurope – a European research consortium is laying the analytical foundation for a new development strategy that will enable a socio-ecological transition to high levels of employment, social inclusion, gender equity and environmental sustainability. The four-year research project within the 7th Framework Programme funded by the European Commission was launched in April 2012. The consortium brings together researchers from 34 scientific institutions in 12 European countries and is coordinated by the Austrian Institute of Economic Research (WIFO). The project coordinator is Karl Aiginger, director of WIFO.

For details on WWWforEurope see: www.foreurope.eu

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