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

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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.

Find part III "Credibility of the REACH Regulation: Lessons Drawn from an ABM" 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

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Summary

1. Introduction

Assessing climate change related challenges is at the core of the current European environmental policy agenda.

On the one side, the Europe 2020 strategy (EC 2010a, 2010b) set the goal, for European Countries, to achieve a 20% reduction in greenhouse gas (GHG) emissions compared to 1990 levels, a 20% share of renewable energy sources used in final energy consumption, and a 20% reduction of final energy consumption compared to business as usual scenario to be achieved through improved energy efficiency.

On the other side, with the launch of the policy framework for climate and energy for 2030 it has become even clear that Member States are expected to further improve their efforts towards a low-carbon economy. ETS and non-ETS sectors are indeed subject to the new target of reducing greenhouse gases emissions (GHG) of 40% with respect to 1990 by 2030 (EC, 2014).

How to achieve these targets depends not only on the choices made on the available policy instruments (which will be discussed into Section 3) but also on the effects that policies have on competitiveness, either at a micro, meso or macro perspective.

Since the Porter Hypothesis has been formulated (Porter & Van der Linde, 1995) emphasis has been given to the potential competitive and productive gains (rather than losses) that might be deriving from the adoption of stricter environmental regulation. This Hypothesis has been argued to consist of three versions by Jaffe and Palmer (1997). The 'weak' version basically postulates that environmental regulations stimulate innovation productivity. The 'strong' version argues that regulation-driven "innovation offsets" might exceed the costs of compliance, thus might result in net productivity gains. Lastly the 'narrow' version posits that well-designed regulations give firms greater incentives to innovate and thus will have less adverse impact on productivity.

Understanding how environmental policies can avoid harming growth, either in strong, weak or narrow terms, is indeed a crucial issue in designing policies.

Strong empirical research effort has been devoted at the analysis on the effects of environmental policies both on innovative activities (mainly version of PH) and on competitiveness (narrow or strong version of PH).

With respect to the first group, literature mainly recognizes that regulation strongly induces technological change (Brunnermeier & Cohen, 2003; Costantini & Mazzanti, 2012; Horbach et al.2012; Jaffe & Palmer, 1997; Johnstone et al. 2012; Johnstone, et al. 2010; Lanjouw & Mody, 1996; Rennings & Rexhäuser, 2010). These empirical evidences in other terms support the hypothesis that properly designed policies foster firms' decisions to improve their products or production processes introducing environmental innovations.

With respect to the second group, the effects of environmental policies on productivity might be more complex than those on innovation, as regulation may improve productivity in some specific activities in the short run but at the same time might engender counter indirect effects.

Berman and Bui (2001) found that air pollution regulation in the oil refining industry determined a significant productivity. Contrarily, Gray and Shadbegian (1998) in analysing the pulp and paper industry found that pollution abatement investments “crowded out” more productive investment and Greenstone (2001) found a negative productivity impact engendered by air pollution regulation.

In principle, at the aggregate level it might be that regulation eliminates less efficient firms thus rising productivity but it might also contrarily be that it acts as an entry cost that, in reducing competition, lowers productivity levels. All in all “empirical research on the productivity effects of environmental policies is largely inconclusive. Results are usually very context-specific and hence of little use for policy makers deciding on which tools to choose to tackle a particular environmental issue” (Kozluk and Zipperer, 2013:21) and overall “a priori, it is however unclear whether these indirect effects are negative or positive, or whether they are large enough to outweigh the drag of the direct effect” (Kozluk and Zipperer, 2013:9).

Indeed, the greatest conflicts in the literature arise in understanding how regulation affects competitiveness, as early studies even concluded that a negative link between regulation and productivity existed (Palmer et al., 1995). In a review by Ambec et al. (2013) the conflicting previous results have been mainly explained in terms of a set of factors such as the environmental problem addressed by regulation, the sector and market conditions, the methodology followed and firms specificities in terms of management.

Section 2 presents a description of environmental policies by type of policy instruments. Section 3 discusses the role of innovation policies and section 4 outlines a specific type of regulation at EU level for chemicals. Section 5 concludes.

2 Taxonomy of environmental policies

Environmental policies are built through the adoption of one or possibly a combination of a set of policy instruments. According to their nature, those might be classified as it follows (OECD, 2009):

1. *Market / Incentive-based instruments*
2. *Command and Control regulation instruments*
3. *Voluntary* (also called negotiated) *agreements*
4. *Information / Education-based instruments*

The market-based and regulatory instruments “may be thought of as ‘hard’ instruments, because they impose explicit obligations, whereas voluntary and information-based instruments may be thought of as ‘soft’ instruments, because they rely more on or seek to stimulate discretionary activities ” (Ekins, 2010: 282).
This section discusses these groups of policy instruments, combining the description of the instruments with some examples of effective policies at stake and their strengths and weaknesses in order to provide (into Section 4) some prescriptions on how to choose among them.

2.1 Market or Incentive Based Instruments

The first set of existing instruments aims at indirectly reducing environmental pressure by introducing market incentives that correct for externalities and balance the private with the social prices. Such instruments span form emissions trading, environmental taxes and charges, deposit-refund systems, subsidies and compensation mechanisms and green purchasing (EEA, 2006).

These instruments may encourage firms towards pollution control as it becomes their own interest and also allow to collectively meet policy goals (Stavins, 2003).

Emission trading schemes may mainly consist in cap-and trade or credit system.

Cap-and-trade systems impose an upper threshold for selected pollutants (cap) and then permits to pollute are allocated and traded (trade) in order to reach a cost-effective way to reduce emissions. The European Trading Scheme (EU ETS), established under the Directive 2003/87/EC, is a concrete example of cap-and-trade system and the largest available in the world, which has been set as the cornerstone of EU's strategy for addressing climate change. EU ETS, launched on January 2005, set a legally binding cap on CO2 emissions and equivalents (nitrous oxide (N2O) and per-fluorocarbons (PFCs) that covers power and heat generating plants, energy intensive industry sectors (including refineries, steel works and production of iron, aluminum, metals, cement, lime, glass, ceramics, pulp, paper, cardboard, acids and bulk organic chemicals) and aviation. The European cap was concretely translated into country caps (National allocation plans) and a market of allowances has been built, that gives those who hold the permit the right to emit one ton of carbon dioxide (CO2) or equivalent gases per permit. The sectoral distribution of national caps has been established in a decentralized way at each country level.

In a first phase (2005-2007), the testing phase, allowances were distributed free of charge following the principle of historical emissions (*grandfathering*), or of benchmarking based on projected emissions for new entrants. The choice of allocation free of charge to reduce resistance from industry by offsetting part of the adjustment costs (Zetterberg, 2014). However this ex ante free allocation has the drawback of reducing the consensus around the policy if this is perceived as unfair because it gives dirty emitters more allowances than to firms who already moved to cleaner production techniques. A penalty for non-compliance to the cap was set as well as national registers to monitor allowances. In a second phase (2008- 2012) allowances were still distributed for free, but the penalty has been increased and the amount of emissions covered by the cap was reduced by 6.5%. The last phase substituted free allowances with an auctioning process and moved the allocation from national governments to the central authority. For sectors which are not covered by the EU ETS each member state has to individually design measure that lead to a 10% reduction in emission by 2020, compared to 2005 levels. Although the EU ETS has been seen as possible bench for a global cap and trade system, its application presented a lot of problems spanning from the over-allocation of allowances in the first phase and transparency problems (e.g. Vlachou, 2014) to the apparently neutral effects of EU ETS on innovative activities (Borghesi et al. 2012; Calel & Dechezleprêtre, 2014). EU ETS effects on CO2 reduction are instead less controversial, as previous empirical literature outlined its positive environmental effects (Wagner et al. 2014a; 2014b). EC proposed indeed a strong revision of the Scheme for its third phase 2013-2020 (EC 2008).

Credit systems instead of imposing a quota on emissions set a minimum level on the emission performance and participants receive credits from the emission reductions they achieved with respect to the selected baseline. An example of this system is the Clean Development Mechanism (CDM) of the Kyoto Protocol (CDM) aimed at favoring technology transfer that gives industrialized countries to develop or finance projects that reduce greenhouse gas emissions in other countries to obtain emission reduction credits. Furthermore, CDM gives technical and financial support for the diffusion of green technology towards countries who have not accepted the emission reduction targets (Dechezleprêtre et al., 2008).

Environmental taxes and charges are ways to internalize in the producers those external costs that are spread over the society in terms of environmental damage, for instance by imposing a tax on pollutant activities.

A Carbon tax is probably the most common type of environmental tax. Regulation sets a price for CO2 (or CO2 equivalent) emissions which the polluters is required to pay for its emissions.

Alternatively the tax can be set on inputs of the production process, for instance on fuels, water usage or pesticides or on outputs, for instance on air tickets. De Serres et al (2010) provide a synthesis of the existing taxes or charges by environmental domains for separately considered OECD countries.

Not only Co2 emissions can be taxed, but other emissions as well: SO2 and NOx are under an emission tax in several countries e.g. Norway, Sweden, Finland, the Netherlands, France, Slovenia, although with a quite high variation of tax rates (Requate, 2005).

A recent EEA study (EEA, 2014) shows that the debate on environmental taxes has not lead to a widespread application of such an instrument. During 1995–2012, EU-27 environmental taxes as a percentage of GDP fell indeed from 2.8 % in 1999 to 2.3 % in 2008, while environmental taxes as a percentage of total tax revenues from 6.9 % to 5.9 % (EEA, 2014). Those taxes are mainly depending on energy taxes, which contribute to the largest share.

Morley (2012) empirically tested at EU wide scale the effectiveness of environmental taxation on both pollution and energy consumption. His findings are of an effective negative effect of regulation on pollution, which decreases as a consequence of the introduction of environmental taxes, while limited effect is found for the use of resources, in particular energy consumption. This lead the author to conclude that the overall consequences of depend also on the structure of other tax levels.

The potential positive side effect of environmental taxes deserves consideration for their positive role for fiscal consolidation, which make them less detrimental than other taxes for countries growth (EC, 2012; 2013). Irrespectively on the concerns on the negative effects of environmental taxation on competitiveness, not only carbon pricing schemes are actually not found to engender any statistical significant impact on electricity retail prices (EC, 2014), furthermore, revenues from the tax can be reinvested by the government in eco-innovation, increasing both patenting and thus technology efficiency employment (EEA, 2011) and increased efficiency of technology. In a study by De Vries and Medhi (2008) it has been found that an increase in fuel prices by 0.1 US$ per litre created 14 % increase in patenting activity.

However, for environmental taxes or cap and trade systems to be really effective, an harmonization of environmental policies across countries is required. In the absence of such an harmonization there exist a concrete risk of relocation of production toward countries having adopted less strict regulation, also known as “carbon leakage”. The industrial relocation not only would weaken the environmental effectiveness of a policy, but would also result in deep costs for the society in terms of loss of jobs. As a consequence to that, energy-intensive firms usually find grants or exemptions in the presence of a carbon tax, even though this does not make the polluter-pays principle effective (Martin et al., 2014).

Instead of adding a tax on pollution, the policy maker can alternatively subsidize environmental-friendly activities, to directly encourage the reduction of negative externalities. The subsidy can mainly take the form of a grant , a tax reduction or of a soft loan[1]. One of the most typical examples is a feed-in-tariff, which is aimed at favoring the uptake for alternative energy technologies. Such tariffs are mainly used for the uptake of solar energy technologies.

Concrete examples of grants at stake range from the Flander’s Region grants to farmers to support sustainable and organic farming to Slovenia’s subsidies for housing energy efficiency improvements for households. Tax reductions have been widely implemented as well, e.g. Italy’s tax reduction of 0.03€ per kWh granted to users of biomass heating systems or Belgium’s investment deduction for "green" R&D investments.

The interplay between existing subsidies and environmental taxes or charges may also affect the overall environmental performance of a country. Taxes have indeed a key role in compensating for removing harmful subsidies, in the phasing out phase of environmentally harmful subsidies, as “Environmental taxation and removing environmentally harmful subsidies can unlock the economy from the unsustainable path as these policies will ensure that the real costs of resource use and environmental pollution are paid by consumers and producers.” (EEA 2014: 71)

The last instrument belonging to the category of market or incentive based systems are deposit refund systems. Those type of instruments usually act on products, such as plastic bottles, and work as a charge on the good for its disposal which is compensated by a subsidy when it is returned to a collection point. Such a system is in place for the deposit and refund of plastic, glass and aluminum bottles in most of European countries e.g. Czech Republic, Denmark, Estonia, Finland. Germany, Hungary, Netherland, Poland, Slovenia.

2.2 Command and control regulatory instruments

Another category of instrument is the one labelled as “Command and control”. This is built by non-market based instruments, as prices are no longer changed, rather standard or obligations are imposed or directly or in the form non-monetary incentives of command and control.

[1] Soft loans are low rate or interest-free loans provided by financial institutions to favor the acquisition of item that help the transition towards sustainability. An example of such loans is providing households with loans aimed at purchasing or installing items recommended for their home to be sustainable.

Institutions could define a framework or performance standard or outcome to be met, or at technology to be used.

Examples of concrete instruments of this field are specific performance standard on vehicle efficiency that limit the amount of emission per unit of output, or the imposition to operators to use specific abatement technologies. Further examples of this instrument are regulations that ban the use of specific products or that impose the use of certificates or registry over harmful substances. The California Zero Emission Vehicle (ZEV) Programme launched in 1990, is an example of technology forcing command and control regulation, as it imposed 10% of sold automobiles to be ZEVs by 2003.

To be considered is not only regulation's direct effect on countries adopting it but also on countries exporting to the adopters, who might be required to fit the standards that have been set, thus pushing the international diffusion of the standard. In diffusing the standard, this in turn promotes the development and diffusion of environmental technologies through 2 main channels. On the one hand exporting countries should modify their processes and products to fit the regulation. On the other hand, environmental regulation implemented in a country can push its exports towards external countries if these ground their policies on the basis of the existing stricter market (EEA, 2014).

One significant example of the capability of an internal regulation to influence on other countries' regulation is the European Chemical Regulation, REACH, as it affects all substances that are *manufactured* or *marketed* in the EU, i.e. all chemicals that are either exported or imported to the EU, thus impacting third countries as well. Countries outside EU, in order to trade within EI are indeed required to fit the standards set by the regulation and, more precisely, to register the chemical substances used. Moreover, regulation of chemicals in countries outside EU are aligning to fit REACH (EEA, 2014).

When a standard on the use of a particular technology is set, it might however engender losses when it create a technological lock-in or it prevent from the development of alternative and better technologies. The point is that technology forcing regulation refer to the best available technology available in the time the regulation is established, while standards should be dynamically further developed over time, in order not to force EI beyond the current technological frontier (Jänicke & Lindemann, 2010). Technology standards they tend to "freeze the development of technologies that might otherwise result in greater levels of control" as "no financial incentive exists for businesses to exceed control targets, and the adoption of new technologies is discouraged" (Jaffe et al., 2002; 50).

For this reason, although they might have positive environmental effects, command-and-control regulations are considered as not dynamically efficient, as do not provide enough long-term innovative incentives. The effort towards the standard stops indeed when the goal has been reached. Contrarily, the incentive in a market based system seem to be stronger, as it does not disappear once the standard or the target has been met.

2.3 Voluntary agreements and information based instruments

Softer typologies of instruments are those labelled as “Voluntary agreements” and “information based instruments”.

Voluntary agreements are at stake when institutions and firms or particular industrial sectors voluntarily coordinate for the adoption of pollution reduction strategies. The nature of such agreements is broad and sanctions might be set as well for non-complying actors. The agreement can either be on a specific target to be reached, e.g. the Flanders Region’s Covenant on NOx and SO2 emissions from electricity producers' installations, or on the implementation of a specific programs aiming at improving environmental performance, e.g. the Czech Republic’s Eco-Labelling system negotiated with the Ministry of the Environment.

The use voluntary approaches, is discussed as being appropriate when pollution emissions cannot be adequately monitored at the source or when it is not clear and unambiguous which is the input or output of the production process that should be under a market-based instruments. For instance it might not be clear whether to set a tax on a specific input or output.

It follows that the efficiency of these instruments in reducing externalities is considered insufficient, and their role is seen mostly as a complement for already existing policies “when information about the environmental impact of products or available clean goods or activities is lacking and that it is not too costly for the government (or firms) to provide such information” (de Serres et al 2010:29).

Information based instruments are instead means to improve consumer awareness on environmental impacts of goods on the market or on the alternatives available. Examples of these instruments are product certifications and labeling, such as eco-labels, which inform consumers on the environmental contents of the products in the market, or product’s lifetime energy use or its greenhouse gases’ emissions. Labelling and certifications may both be mandatory or voluntary in their nature.

2.4 How to choose?

How to choose among the set of instruments that have been previously described is not an easy task.

According to Requate (2005) under competitive conditions market based instruments usually perform better than command and control ones. An explanation to this is that environmental taxes and in general market based instruments provide longer term and more persistent incentives to innovate than others and, moreover, flexible and thus more dynamic environmental policy instruments are seen as more effective than static ones (de Serres, et al 2011). In addition to this, the innovative effects of environmental policies are stronger when a long time horizon is set for the duration of the policy.

Johnstone, Haščič, & Kalamova (2010) propose additionally to analyse environmental policies in terms of more specific characteristics of different instruments rather than on their market vs non market nature. In particular they focus on the following characteristics of the policy instrument: stringency, predictability (or certainty), flexibility, incidence, and depth of the instruments. Here follows a description for these characteristics.

- Stringency depends on how ambitious is the policy target, with respect to the baseline scenario

- Predictability depends on how much the policy signal is consistent, foreseeable, and credible

- Flexibility depends on the possibility given to the innovator to its best way to meet the objective set

- Incidence is related to the question: does the policy target the externality directly, or is the point of incidence a 'proxy' for the pollutant?

- Depth is related to the question are there incentives to innovate throughout the range of potential objectives?

According to these criteria, the optimal policy instrument is such when it is "stringent enough to encourage that level of innovation which results in the optimal level of emissions; sufficiently stable to give investors the necessary planning horizon to undertake risky investments in innovation; sufficiently flexible to encourage innovators to identify innovative solutions which have not yet been identified; targeted as closely as possible on the policy objective in order to avoid misallocation of innovation efforts; and, provide continuous incentives to develop abatement technologies which could (in theory) drive down emissions to zero (Johnstone at al. 2010: 7).

So far we outlined a set of suggestions that might help the policy maker in the choice of one instrument with respect to another, either based on the distinction between market or non market based one or on the more intrinsic nature of the instrument according to its stringency, predictability, flexibility, incidence, and depth.

Evidence outlines that it is pretty common for countries to deploy not just one instrument rather a combination of instruments in designing environmental policies. This habit is usually labeled 'policy packages' or 'instrument mixes' or policy mixes. As all the listed typologies of environmental instruments can stimulate environmental innovations, there is a tendency to combine them all in a mixed policy (OECD, 2009), which is in principle able to correct for the predominant market failures and institutional capacities of respective countries (De Serres et al 2010; 2011).

However, the "Tinbergen Rule" for the design of public policies states that for each policy target one policy instrument has to be employed (Tinbergen 1952), as in the presence of a bigger number of instruments than targets only increases costs and not effectiveness, leading to generally waste resources. European public policies – and environmental ones as well - often violate this rule by incompletely implementing instruments or by adopting multiple instruments to reach the same target (Böhringer et al., 2009; Serres et al. 2010).

An example of this violation is the joint adoption of the European trading Scheme – a cap and trade mechanism – and a feed-in tariff for the uptake of photovoltaic energy diffusion might thus create a bias and signal the market with conflicting message that can result in an overall inefficiency of both policies. This counter-productive effects of policy mix face is associated with the overlaps of instruments, that is depicted anytime the same actor (consumer, firm, institution) faces more than one instrument devoted at reducing one (same) environmental externality. The previous example of a cap-and trade system mixed with a feed-in-tariff or a carbon tax is a case of possible risky policy mix. Another example, suggested by De Serres and co-authors (2010) is the case of mixing performance standards for electricity producers that set a minimum share of power to be generated from renewable sources a carbon tax on the electricity sector.

Furthermore, evidence suggests that the proliferation of policy instruments has not even stopped the rise in CO2 concentrations in the atmosphere (Huppes, 2011). This lead some scholars to argue that more powerful system need to be developed. A proposal in this direction is the establishment of a global carbon deposit system (Huppes, 2011), based on pricing carbon emissions from any source and any country. Wood and Jotzo's (2011) contribution goes in the direction of empirically test the economic-environmental effects of a combination of an environmental tax to be added to the emission permit price. This is seen as a viable option, although in violation of the Tinbergen rule-as the tax is in principle added to permits' price- but under certain conditions. Coherently to this, the ENTRACTE Project policy suggestion has been formulated as follows: although instruments overlap, they can be complementary and mutually re-enforcing when they lead to cost reductions (ENVECON, 2014: 4).

When deciding for which policy instrument to be chosen to assess a specific environmental problem, not only there is an issue on how to choose among the available instruments and how to construct them to be effective but also an issue on how to combine this choice with already existing regulations. This difficulty appears to be translated into very heterogeneous choices made by EU Member States both in terms of instruments and in terms of magnitude of the implemented policy. The ENTRACTE Project performed an assessment of EU Climate Policy and delivered a screening of Member States' policies portfolio which truly highlights strong differences among countries both in terms of the instruments chosen and in their effects (Landis et al, 2013).

2.5 Do environmental policies foster the rise of pollution havens?

A further aspect that deserves consideration when discussing about environmental policies is their possible negative side-effect.

The increase in environmental policies stringency, can indeed generate, as an unexpected effect "pollution havens", which overall eliminate the environmental effect regulation. According to the pollution haven hypothesis, differences in policy stringency among countries can encourage those exposed to less stringent regulation to gain competitive advantages in the production and export of "dirty" products. Those facing stricter regulations will contrarily be tempted to relocate in other countries their production, in order to escape regulation. Although evidence on this hypothesis is still inconclusive (Brunnermeier & Levinson, 2004; Cave & Blomquist, 2008), it is an issue that needs to be considered deeply when designing policies at the EU level.

As Cave and Blomquists's (2008) empirical analysis points out, there is evidence of a greater amount of energy imported goods by EU from countries with weaker regulation during increased in a periods of EU more stringent environmental policies.

3. Innovation policies and the environment

Since the seminal contributions by Nelson (1959) and Arrow (1962), a wide body of literature has acknowledged the basic fact that markets are likely to fail in the identification of the correct amount of resources to be allocated to research activities.

In this perspective, government have devoted significant shares of public budgets to fund not only programs aiming at fostering the generation of new scientific knowledge within research oriented institutions, but also innovative activities carried out by private firms (OECD, 2007). Despite this, the real effect of R&D subsidies on firm's innovative activities is not clear-cut, as it is possible that public subsidies crowd-out private investment (David and Hall, 2000; David et al., 2000; Hall and van Reenen, 2000; Bloom et al., 2002).

Different motivations have been provided for potential drawbacks of public R&D incentives. The first issue concerns asymmetric information and the consequent difficulty for policymakers and program officials to know which firms deserve to be funded (Grossman, 1991; Stiglitz and Wallsten, 2000). Other strands of literature emphasize that the opportunities relate to public support provides industries and other interest groups with an incentive to invest large resources in unproductive rent-seeking activities such as lobbying (see e.g. Tollison, 1997). Moreover, the efficiency of R&D public support may be further jeopardized by bureaucrats maximizing their own private utility rather than the social welfare (Link, 1977).

The allocation procedures of public subsidies do matter in this context. Two main mechanisms can be devised as far as the allocation of public subsidies to R&D activities is concerned: i) automatic procedures typically associated with tax expenditures; ii) with discretionary procedures based upon the quality assessment of research projects. The main difference between tax credits and direct grants is that the former represents a general measure that may apply to all industries and firms independently from their specific characteristics. Hence, the most important benefit of tax credit programs as compared to direct grants is that they minimize the discretionary power public agents holds when allocating public resources (Musgrave and Musgrave, 1973).

Much literature has however criticized automatic procedures, mainly based upon tax reductions, and stressed the advantages of discretionary procedures based upon the actual screening of research projects and of direct funding of public research programs (Mazzucato, 2013). Tax credits may imply to provide support to an array of activities that often can hardly be classified as R&D, which are likely to be performed by firms that are not actually able to properly carry out research projects and to make an effective use of the subsidies. In this respect, the risks of opportunistic behaviour seem to be very relevant. Firms often classify some expenses in their balance sheets as R&D, while they actually concern other kinds of business activities barely related to research. In parallel, firms' lobbying activities exert relevant pressure on government authorities in order to adjust the definitions of what is actually meant by "R&D" so as to broadening the range of allowable costs (Alt et al., 2010). Moreover, according to David et al.(2000), private firms are likely to use tax credits prioritizing projects with the highest private rates of return, focusing their research efforts on projects with short term prospects. These projects are not necessarily the ones deserving public support, which should in turn be targeted to projects with the largest gap between social and private returns. Hence, even though tax credits represent a straightforward mechanism to providing public support to R&D and to minimize problems related to discretionary decisions from public actors, they do not seem to be the most efficient tool to spur innovation activities (Mazzucato, 2013).

Discretionary procedures based upon quality assessment of research projects to allocate R&D grants, are potentially better suited to enhance innovation investments as they are more likely to support better research projects, and provide a framework helping identifying and supporting potential complementarities among innovative projects (Mohnen and Roller, 2005). As a matter of fact many countries do rely on discretionary selection procedures, and the empirical literature showed that despite the potential drawbacks associated with them, selective public subsidies, in general, do have a positive effect on R&D investments (Antonelli and Crespi, 2013).

The more recent innovation systems approach has further extended the range of legitimate justification and scope for public intervention in this field (Metcalfe, 1995; Georghiou and Metcalfe, 1998; Edquist, 2001). In particular, a growing body of economic literature suggested that traditional economic approaches are inappropriate for dealing with the dynamics of structural and adaptive changes in economic systems (Rammel and van der Bergh, 2003). The relevant lesson emerging from the systemic approach suggests that innovation is a complex evolutionary process distributed in a system of different agents whose behaviour and interactions are governed both by market forces and by non-market institutions (Metcalfe, 1995).

Agents' interactions and the institutions governing them determine the innovative performance of the system. The systemic framework opens up a new perspective for policy making in general and, more specifically, for the design of an appropriate policy structure to foster the dynamics of eco-innovations. This approach highlights the interactions and interdependencies between different policies, and shows how such interactions affect the extent to which policy goals are realized.
This shift is exemplified by the increasing interest in the concept of 'policy mix' into which several policy instruments belonging to the spheres of environmental policy and innovation policy co-exist (Flanagan et al., 2011). In this context the choice of instruments and the analysis of their interactions represent crucial decisions for the formulation of policy design.

So far, the incentive to generate and adopt innovations that improve environmental performances has been mainly provided by environmental policies, which are more and more seen as key to enact inducement mechanisms. However, though environmental policies may well represent a stimulus for new research activities, innovation systems should be equipped with adequate scientific and technological knowledge in order for the economy to creatively respond to changes in policy constraints (Costantini and Crespi, 2008). Innovation policies can be well designed to support R&D activities within specific technological domains or related to specific industrial activities. This represents an opportunity that has not been fully exploited already. There is in this respect a substantial lack of coordination between environmental and innovation policies that needs to be addressed to increase the effectiveness of both (Costantini and Crespi, 2013; Borghesi et al., 2013).

3.1 Innovation-oriented *environmental* policy

As environmental innovation (EI) are "special" innovation affected by a "double externality" (Rennings, 2000), the need for innovation policies to be specifically directed towards the development of EI emerges, as traditional innovation policies might not be enough to spur their development and adoption, given their peculiarities. Furthermore, empirical analysis on the determinants of EI (e.g. Horbach et al., 2012; Rennings and Rexhauser, 2011) stress the central role of policy in inducing EI, and empirical analysis have confirmed regulation's pivotal role (Veugelers, 2012).

Not only the existence of innovation oriented environmental policy matters in stimulating EI, but also its stringency. In other words, it is the stringency of a regulation to affect the rate and direction of green technological change (Johnstone et al. 2008; 2010; 2012).

Some prescription on how innovation oriented environmental policies should look like have emerged from previous contributions.

Del Rio and coauthors (2010) suggest some characteristics that policy instruments should have, which they label general features, or "framework conditions". For instance policy aimed at overcoming barriers to EI, for which a suggestion of simultaneously use and better integration of environmental and technology policies and of searching for a balancing between short-term protection and longer-term promotion of radical EI in order to avoid technological lock-ins is suggested. Lock-in in suboptimal technologies might be indeed a negative side-effect of a policy, and this will favor the uptake of 'incremental' innovations, based on improvement of already existing technologies, rather than radical and systemic, e.g. the development of new technologies or products or services.

Furthermore, the complexity of EI suggest the need of policy instruments to fit each different phase of the process, from invention to diffusion, as effective policies should differ along the process (Jänicke & Lindemann, 2010). Innovation policies to support R&D might favor the invention phase, a command-and-control policy setting a technology standard can influence both the invention and the innovation phase, while information mechanisms such as eco-label can help the diffusion of EI.

More precisely, market based instruments can influence a the whole innovation cycle, as they alter the direction and rate of technological change.

Some further prescription on how an innovation oriented environmental policy should be is that the ecological effect of EI should be the priority of the innovation. In other words "Environmental policy should not just promote any kind of environmental innovation but seek to maximise the ecological effectiveness of technology development" (Jänicke & Lindemann, 2010:129). The authors differentiate between *weak* EI, e.g. incremental or radical innovation with low market penetration rates, and *strong* EI, e.g. incremental or radical EI that have high market penetration rates and thus an high environmental impact. All in all, greater environmental improvements are associated with radical EI with high penetration rates as “it is the replacement of coal-fired power plants by renewable energies rather than continuous incremental efficiency gains that will ensure the decoupling of environmental pressures from economic growth and the absolute reduction of environmental impacts” (Jänicke & Lindemann, 2010:130). Coherently, policies should be focused on the uptake of *strong* EI, and in particular on radical ones, to maximize the environmental benefits.

Furthermore, the development of R&D policies devoted at the uptake of EI can stimulate the invention and then the uptake of EI, as it is true already for standard technological innovations that we discussed in Section 3. If we label such policies as “environmentally oriented R&D policies”, i.e. R&D policies applied to the green realm, we may find support that “traditional” innovation policy instruments do stimulate green R&D as well, which, in turn, is a source for green innovation.

One solution is an Intellectual Property Rights IPR policy that enforces the functioning of the existing IPR system or, in its absence, creates a new one. This is in line with the Lindhal’s approach for public policies when dealing with a problem of under-investment in innovative activities when the private benefits of such activities are lower than their social benefits. The solution proposed is that of making knowledge a “commodity”, whose benefits are fully appropriable to the firm, by creating a (temporary) monopoly over the invention. This solution calls for the development of an IPR system able to protect inventions through formal protection mechanisms such as patent or trademarks.

Another solution is in line with the Samuelson’s approach for public policies when there is risk of under-investment in innovative activities. This calls for the need of public policies to invest in R&D, in this case through eco-innovation research programmes, in order to substitute the missing provate investment with public private ones.

Lastly, what is called a “lead market approach” for EI needs a discussion in this framework. A lead market policy can be defined as a demand-side intervention aimed at promoting environmental technologies that can engender first mover advantages for national firms and favor the early-adoption of EI and thus their invention and diffusion. It characterized by the existence of price, demand, transfer, export and arket structure advantages that benefit firms operating in such markets (Beise and Rennings, 2005). Innovation developed in a lead market conditions are more likely to become a dominant design and to be then globally adopted as they have been developed and protected in a market niche and they are then able to spread to other countries when the environmental technology is established (Quitzow et al. 2014).

To sum up, when the policy goal is to spur the uptake of EI, the adoption of a combination of instruments, policy mix, is not seen as a problem anymore (contrarily to what emerged into Section 2), rather as a value added when environmental and innovation or technology-specific policy are combined. Such combination of policies can be facilitated by the development of governmental transition management schemes, in which the government facilitates and plans the transition to a greener economy by combining available instruments.

When this mix is optimal and covers the entire innovation life-cycle, literature thus uses the term "smart regulation" (Ekins and Venn 2006). The explanation to this (apparent) contradiction lies in the complementarity between environmental and innovation regulation. The first is designed to reduce negative, environmental externalities, while the second addresses positive externalities, mainly knowledge-related externalities, deriving from problem in appropriability of the benefits of innovation investments.

Neglecting the need to combine environmental and innovation policies can lead to "unintended and very undesirable outcomes" such as the "green paradox" or a technological lock-in (van den Bergh, 2013: 18). The green paradox is conceived as a case of rebound effect. In the presence of a technology policy e.g. renewable energy subsidy and in the absence of an environmental regulation e.g. a carbon tax, the subsidy can increase the supply of electricity, reducing the prices for fuels and thus increasing their extraction and increasing GHG emissions. Contrarily to the green paradox, in the presence of environmental regulation without an innovation one it can be more likely to observe technological lock-ins as "Selection pressure will then favor currently cost-effective technologies which may lead to an early lock-in of these at the disadvantage of technological alternatives that are more desirable from a long-run perspective" (van den Bergh, 2013: 18). The presence of initial economic advantages for already existing technological trajectories built around dirty technologies can create lock-ins that, in the absence of a proper policy, may hamper the uptake of EI. But also the presence of inadequate policies can create such lock-ins. The case of internal combustion engines, described in Oltra and Saint Jean (2009) is an example of a dominant design of a dirty technology which has been continuously made more efficient through incremental innovations. This improved its environmental efficiency, but also lead to technological inertia that prevented the development of radical innovations as alternative engine technologies e.g. electric or fuel cells vehicles. All in all, if adopting evolutionary lens can even be detrimental when it reinforces existing inefficient (and possible more polluting) trajectories (Cecere et al., 2014).

However, although environmental policies are seen as key drivers of EI, still no unanimity is found on which policy instruments are best suited to support their uptake (Ekins, 2010).

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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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