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Environmental Policy Stringency, Innovation and Productivity in EU Countries: is there a Double Dividend?[1]

Roberta De Santis and Cecilia Jona Lasinio[2]

Sommario

In uno scenario internazionale sempre più integrato, la regolamentazione ambientale potrebbe avere un ruolo importante nel determinare i vantaggi comparati delle nazioni. La protezione ambientale è tradizionalmente percepita come un costo addizionale imposto dai Governi alle imprese, con ricadute negative su competitività, crescita e occupazione. Alcuni analisti, tuttavia, hanno criticato questo paradigma. In particolare, Porter e Van der Linde (1995) ritengono che l'inquinamento sia spesso associato a uno spreco di risorse e che una legislazione ambientale più restrittiva possa stimolare l'innovazione con ricadute positive sulla produttività che più che compensino i costi addizionali. Questa è nota come l'ipotesi di Porter e suggerisce l'esistenza di un doppio dividendo di natura economica e ambientale determinato dall'implementazione di politiche per la protezione dell'ambiente.
In questo lavoro, si adotta un approccio macroeconomico per analizzare l'impatto delle differenti politiche ambientali sull'economia nel complesso. I risultati preliminari mostrano che la "Narrow Porter Hypothesis" non può essere rifiutata. Sembrerebbe, infatti, che le politiche ambientali nel periodo 1995-2008, in media, non abbiano peggiorato la competitività degli Stati membri dell'Unione Europea, fornendo uno stimolo all'innovazione e alla produttività.

Parole chiave: Regolamentazione ambientale, produttività, innovazione.

Abstract

In a globalised framework, environmental regulations can play a crucial role in influencing countries' comparative advantages. The conventional perception about environmental protection is that it imposes additional costs on firms possibly reducing their global competitiveness with negative effects on growth and employment. However some economists, in particular Porter and Van der Linde (1995), argued that pollution is often associated with resource waste and that more stringent environmental policies can stimulate innovation that may over-compensate for the additional costs ofcomplying with these policies. This is known as the Porter hypothesis and suggests the existence of a "double dividend" for both economic and environmental aspects, related to the implementation of environmental regulations. In this paper, we adopt a macroeconomic approach to investigate the impact of various environmental strategies on the economy as a whole. Preliminary findings show that the narrow version of the Porter Hypothesis cannot be rejected and that the choice of different environmental policies appears to be neutral. Interestingly enough, it seems that the environmental stringency measures adopted between 1995 and 2008 on average did not erode the competitiveness of EU Member States but rather stimulated innovation and productivity, while over-compensating for the additional costs related to these policies.

Keywords: environmental regulation, productivity, innovation.

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The views expressed in this paper are those of the authors and do not necessarily represent the institutions with which they are affiliated. Any errors or mistakes remain the authors' sole responsibility.
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1. Introduction

"Pollution is a manifestation of economic waste and involves unnecessary or incomplete utilization of resources… Reducing pollution is often coincident with improving productivity with which resources are used".
(Porter, van der Linde 1995: 98, 105).

In a globalized framework, environmental regulations can have a decisive role in influencing countries' comparative advantages. The conventional perception about environmental protection is that it imposes additional costs on firms, which may reduce their global competitiveness with negative effects on growth and employment. However, some economists, in particular Porter and Van der Linde (1995), argue that pollution is often associated with a waste of resources and that more stringent environmental policies can stimulate innovations that may over-compensate for the costs of complying with these policies. This is known as the Porter hypothesis and suggests the existence of a "double dividend", for both economic and environmental aspects, related to the environmental regulation.

According to this "new" paradigm, innovation is one of the core elements to guarantee the coexistence of economic growth and environmental improvements (e.g the double dividend). As a consequence, it is extremely relevant to identify sound environmental policy designs to foster the development and diffusion of 'environmental friendly' technologies.

The macroeconomic empirical investigation of the consequences of environmental regulation on aggregate economy is rather scant and it is mostly developed in the context of international trade[2]. Only few studies documented the effect of tighter environmental regulation on productivity and environmental innovation adopting a cross-country perspective but the empirical evidence is rather inconclusive[3].

Specifically, this paper aims to fill this gap and draws on empirical research to investigate the impact of tighter environmental regulation on productivity and innovation on the EU countries.

Few existing empirical studies about the effects of environmental policies on productivity and innovation at the aggregate level for EU or OECD countries are rather heterogeneous and inconclusive[4]. Results are usually very context-specific and focused on different dependent variables (e.g.

[2] R. De Santis (2013).
[3] See table 1 in the appendix.
[4] See Koźluk and Zipperer, 2014.

multifactor productivity adjusted[5], patent counts or efficiency score). Thus the size and the sign of the identified effects are hardly comparable.

The empirical evidence about the positive impact of tighter environmental regulation on environmental innovation is rather weak (Lanjouw and Mody, 1996; Popp, 2006; De Vries and Withagen, 2005). But, the ‘light’ version of the Porter Hypothesis- more stringent environmental regulation will increase environmental innovation is instead well supported by the data. Jaffe and Palmer (1997) and Lanoie et al. (2011) estimate the relationship between total R&D expenditures and pollution abatement costs and found a positive link with R&D.

In a very recent paper, Albrizio et al (2014) look at the effect of environmental stringency policy changes on productivity growth in OECD countries. They experiment a new environmental policy stringency (EPS) index, and test a reduced-form model of multi-factor productivity growth, that takes into account that the effect of countries' environmental policies varies with pollution intensity of the industry and technological advancement. They found that “*productivity growth is negatively affected by the policy change after a year. The negative announcement effect is offset three years after the realization of the policy change”*[6].

We contribute to the existing literature offering a new perspective to evaluate the impact of environmental regulation on innovation and productivity. We investigate both the direct and indirect impacts of various environmental stringency proxies on innovativeness and productivity indicators adopting a cross-country perspective that has been rarely used in the literature. Moreover we distinguish between command and control and market based environmental policy instruments to understand whether the form of regulation can have a differentiated impact on our findings.

We perform the analysis at the macro level since this approach allows to capture the variation both across policies and across outcomes, providing a richer sample and making possible to capture the spillover effects among industrial sectors. Moreover the industry or firm level studies suffer from lack of generality, as they give a very context-specific answer, making their results less interesting for policy making.

The paper is organized as follows: section 1 reports some stylized facts about the emissions levels in the European Union, section 2 describes the data set, the empirical model and the estimation strategy, section 3 illustrates our empirical findings. Conclusions follow.

2. Environmental regulation on climate change in EU: stylized facts

The European Union has long been a driving force in international environmental negotiations that led to agreement on the two United Nations climate treaties, the UN Framework Convention on Climate Change (UNFCCC) in 1992 and the Kyoto Protocol in 1997.

Among the most relevant EU policy interventions there are the introduction of the EU Emission Trading Scheme (Directive 2003/87/EC)[7] and the directives of the 2020 Climate and Energy Pack-

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5 Environmentally adjusted measures of productivity growth are not aimed at answering the question about productivity effects of environmental policies per se. These productivity measures are rather developed to improve the measurement productivity in the first place and can then be used to conduct analyses of the impact of environmental policies. For a broader discussion on this issue see Kozluk T and V. Zipperer, (2014).

6 Albrizio et al (2014).

7 The European Union Emissions Trading System (EU ETS), also known as the European Union Emissions Trading Scheme, was the first large greenhouse gas emissions trading scheme in the world, and remains the biggest. It was launched in 2005 to combat climate change and is a major pillar of EU climate policy. As of 2013, the EU ETS covers more than 11,000 factories, power stations, and other installations with a net heat excess of 20 MW in 31 countries—all 28 EU member states plus Iceland, Norway, and Liechtenstein. The installations regulated by the EU ETS are collectively responsible for close to half of the EU's emissions of CO2 and 40% of its total greenhouse gas emissions. The scheme has been divided into a number of "trading periods". The first ETS trading period lasted three years, from January 2005 to December 2007. The second trading period ran from January 2008 until December 2012, coinciding with the first com-

age on CO2 emission reduction (2009/29/EC, 2009) and renewable energy (2009/28/EC, 2009). Particularly relevant is the European Union Emissions Trading System (EU ETS) that represents somehow a discontinuity with respect to the previous EU environmental policy for the most part designed as command and control policies[8.].

Emissions trading belong to the market-based instruments which can be defined as regulations that encourage firm's behavior through market signals rather than through explicit directives regarding pollution control levels or methods. On the contrary, command and control regulations set uniform standards for firms, that can be technology or performance based. In general, the mainstream neoclassical literature attributes to marked based instruments the property of static efficiency, saving information costs, the possibility of a double dividend, self-enforcement and of promoting innovation better that command and control instruments.

Emissions trading in particular is an instrument based on the creation of a market attributing a price for environmental externalities allowing the actors to internalize the cost related to the environmental negative effects of their activities.

Despite these claims supporting emissions trading systems, recent reviews of the theoretical literature ranking environmental instruments according to their potential innovative spillovers showed mixed results (Kemp and Pontoglio; 2011)[9].

More recently, in 2007, EU leaders endorsed an integrated approach to climate and energy policy and committed to transforming Europe into a highly energy-efficient, low carbon economy. They made a unilateral commitment that Europe would cut its emissions by at least 20% of 1990 levels by 2020. This commitment is being implemented through a package of binding legislation. The EU has also offered to increase its emissions reduction to 30% by 2020, on condition that other major emitting developed and developing countries commit to do their fair share under a future global climate agreement.

Eventually, in October 2014, European Commission agreed new headline targets for 2030, reducing greenhouse gases emissions by at least 40 % from 1990 levels, increasing renewable energy to make up at least 27 % of final energy consumption and a minimum 27 % reduction in energy consumption compared to business-as-usual.

The current projections for 2030, however, indicate that further efforts are required at national and EU level to keep the EU on track towards its new 2030 targets, as well as its longer term objectives to decarbonize the European energy system and cut EU's greenhouse gas emissions by 80 to 95% by 2050.

At country level it can be noticed that the emission of CO^2 in the period 1995-2008 were fairly stable in Italy, France and Germany (chart 1). Differently they were very volatile in Finland and had an increasing trend in Spain until 2005 and then diminished marginally.

[Chart 1]

Thus it seems that not a dramatic progress has been obtained in terms of emission reduction. As for revenues from environmental taxes the behavior of the indicators in the first part of the time

mitment period of the Kyoto Protocol. The third trading period began in January 2013 and will span until December 2020. Compared to 2005, when the EU ETS was first implemented, the proposed caps for 2020 represents a 21% reduction of greenhouse gases.

8 The European Commission explicitly argues that environmental policies and increased competitiveness are not mutually exclusive, but can indeed strengthen one another. An initial commitment to the strategic reorientation of environmental policies in the EU gradually took place since 1987, with the introduction of the 4th Environment Action Program. Since then, Europe increasingly moved away from command-and-control regulation towards the implementation of new market-based instruments.

9 Ex-post empirical analysis on the effects of environmental policy instruments on innovation revealed that the nature of the instrument (market-based or cap-and-control) is just one of the features of the policy setting describing an environmental policy, the other main identifying issues are: stringency, timing, enforcement, combination of instruments and other design issues (Kemp and Pontoglio; 2011).

sample was very heterogeneous at national level but after the second half of 2004 it seems that there was a generalized decrease in all the main European countries (chart 2).

[Chart 2]

For what concerns the environmental patents Germany and France were the top countries in terms of EPO applications followed by Italy that experienced an increasing trend since 2003. Interestingly enough Finland and Spain lagged behind (chart 3). In chart 4 and 5 we show the correlation between the CO2 emissions in metric tons per capita as a difference with respect to the 2020 target and respectively the ICT capital and the R&D expenditure.

[Chart 4]

[Chart 5]

In the charts we divide our sample of observation in two sub samples in order to show the dynamic of the phenomenon at country level. The charts confirm the previous evidence: it is possible to notice that Germany and France show a positive correlation between emission target and ICT and R&D while Spain and Italy and interestingly also Finland show a different behavior. In these countries the increase in ICT and R&D do not correspond at a reduction in the distance to the emission target.

3. Equation, data set and econometric strategy

The Porter assumption has been empirically examined evaluating three different degree of stringency: the weak, the strong and the narrow version of the Porter Hypothesis (Jaffe and Palmer, 1997)[10.]. In this paper we test the narrow hypothesis assuming that certain types of environmental regulation, those designed to target the outcome rather than the design of the production processes, are more likely to increase innovation and improve the performance of the company.

Our empirical strategy is twofold. First we test for the direct influence of environmental policies on productivity growth and on the accumulation of technological and innovation capital (ICT, R&D).Then we investigate whether those countries where the degree of environmental regulation was relatively higher experience faster productivity growth and relatively higher level of innovative activities.

To analyze this assumption we adopt a difference in difference approach as in Rajan and Zingales (1998) who proposed an estimation model with interactions to test the impact of financial development on industry growth. Their approach has been widely adopted in the finance and industry growth literature to analyze the effects of labor market institutions on comparative advantage and productivity (e.g. Cingano et al., 2010; Cuat and Melitz, 2010), to investigate the relation between human capital and comparative advantage (e.g. Ciccone and Papaioannou, 2010); and to examine the economic consequences of firm size, entry regulation, transaction costs, fiscal policy, risk sharing, and foreign aid (e.g.; Michelacci and Schivardi, 2010)

We start from a standard production function augmented with environmental policy variables to check for the direct impact of environmental regulation on productivity growth:

$$\Delta \ln Y = \alpha_1 + \alpha_2 \Delta \ln X + \alpha_3 Z^j + \varepsilon \qquad (1)$$

[10] The *weak version* of the Porter Hypothesis implies that environmental regulation will lead to an increase in environmental innovation. The *strong version* of the Porter Hypothesis claims that the cost savings from the improved production processes are sufficiently large to increase competitiveness. It rejects the assumption of perfect markets with profit maximizing firms and assumes instead that firms are not operating fully efficiently by leaving some profit opportunities unused. Environmental policies might hence induce the firm to rethink their production process.

Where *Y* is an indicator of labor productivity (*LP)* or Total factor productivity *(TFP)* , *X* is a set of controls including measures of innovation capital stock and Z^j is a measure of environmental regulation. If α_3 is positive then our assumption (the Narrow Version of the Porter Hypothesis NVPH holds) is supported. In other words, this would confirm that well designed environmental policies can positively affect productivity growth (e.g. there is a double dividend). Further, the TFP regression results allow to check for the presence of spillovers to environmental stringency measures.

Then we investigate the correlation between a set of environmental stringency proxies and two measures of technological and innovation capital stock (i.e. ICT, R&D) in equation 2 below. The main hypothesis is that environmental regulation is likely to have a positive direct impact on the accumulation of technological and innovation capital. More stringent environmental regulation is assumed to foster ICT and R&D investments since they are key elements to reduce the environmental footprint of economic activities. If this assumption is empirically supported we can also make inference about the channels through which environmental stringency indirectly affects productivity growth.

$$\Delta \ln K^i = \alpha_1 + \alpha_2 \ln Z^j + \varepsilon \qquad (2)$$

If α_2 is positive and significant we can take the results as an “indirect” test of NVPH.

As for environmental stringency indicators it as to be underlined that policy makers can choose amongst alternative policy instruments, a crucial consideration affecting this choice is the impact of the different environmental policy in terms of incentive to develop environmental friendly technologies. In particular, in environmental law and policy two main alternative forms of policy instruments are used: i) market-based instruments that use markets, price, and other economic variables to provide incentives for polluters to reduce or eliminate negative environmental externalities and ii) command and control instruments that are more prescriptive than market-based instruments (i.e. emission standards, process/equipment specifications, limits on input/output/discharges)[11].

We test three different measures of environmental regulation including command and control (i and ii) and marked based provisions (iii)[12:] i) CO2 emissions in metric tons per capita as a difference with respect to the 2020 target[13], ii) the ratification of the Kyoto agreement and iii) the revenues from environmental taxes in percentage of GDP. We included in the estimate a time dummy “2005” in order to catch the impact of the introduction (in 2005) of the European Emission Trading System (ETS).

We included both environmental regulation types because the related literature underlines that the impact on innovation and productivity of marked based vs command and control policy instruments can be different. In particular command and control approaches have been criticized for restricting technology, as there is no economic incentive for firms to innovate[14]. Market-based and flexible instruments such as emission taxes or tradable allowances, or performance standards, are more favorable to innovation than technological standard since they leave more freedom to firms on the technological solution to minimize compliance costs.

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11 The European Commission explicitly argues that environmental policies and increased competitiveness are not mutually exclusive, but can indeed strengthen one another. An initial commitment to the strategic reorientation of environmental policies in the EU gradually took place since 1987, with the introduction of the 4th Environment Action Program. Since then, Europe increasingly moved away from command-and-control regulation towards the implementation of new market-based instruments.

12 In equation (2) we also included a measure of environmental patents measured as number of patent applications to the EPO taken from OECD. In an extensive survey, Griliches (1990, p. 1661) mentions the advantages of using patent statistics as indicators in this kind of analysis..

13 A 20% reduction in EU greenhouse gas emissions from 1990 levels.

14 Swaney (1992), Fischer, Parry and Pizer (2003), Jaffe and Palmer (1997).

All in all, we expect a positive sign for the coefficients of the control variables and the measures of ICT and R&D capital stock. We do not have any a priori on the expected sign of the environmental variables in both equations. A positive sign of ETS, Kyoto agreement, revenues from environmental taxes and a negative sign of the difference of the emission with respect to the target however would be in favor of the hypothesis that the NVPH holds.

Finally, we tested equation 3 including some interaction terms to catch some differential impacts of the various environmental stringency measures on productivity and innovation:

$$\Delta \ln Y = \alpha_1 + \alpha_2 \Delta \ln X + \alpha_3 \ln K_I {*} Z^j + \varepsilon \qquad (3)$$

If α_3 is positive then countries with tighter environmental regulation and higher innovation intensity experience faster productivity growth.

It is worth to notice that all the environmental stringency measures are mainly related to emission reduction and for this reason might have had a strong impact on a broad range of production techniques and competitive advantages also at the aggregate level. Thus they are particularly suitable for our purposes.

Our analysis covers 10 EU countries (Belgium, Germany, Denmark, Spain, Finland, France, Italy, The Netherlands, Sweden, UK, plus USA as a control country) over the period 1995-2008[15]. Annual data are from OECD and EUKLEMS (see for descriptive statistics table 6 in the appendix). As for the empirical strategy, we use a panel data technique. A major motivation for this choice is the possibility to control for the correlated time invariant heterogeneity. We perform an Hausman specification test to check the presence of correlation between explanatory variables and individual effects. Results are reported in the tables: the null hypothesis of zero correlation is accepted, showing that for our purposes the FE provides more efficient estimates than RE estimators[16]

Equation (1) can be affected by endogeneity and measurement errors that will be controlled by means of instrumental variables. At the moment, we do not yet fully control for the biases potentially induced by endogeneity of capital inputs. We only resort to lagged explanatory variables partially accounting for the endogeneity biases Thus, at this stage, our analysis is preliminary and aimed at identifying the presence of simple correlations.

4. Preliminary estimation results

Table (4) shows the first set of equation (1) estimation results. ICT and NON ICT capital coefficients are positive and statistically significant as in the empirical production function literature[17] Among environmental policy indicators, only Kyoto agreement is positively and statistically significantly correlated with labor market productivity (LP) growth. ETS and CO2 emission (as a difference with respect to the target) are not statistically significant suggesting that by means of equation (1) we are not able to capture the differential impact of environmental policies on growth.

However, the findings in Table 2 suggest that the NVPH cannot be rejected and that a deeper investigation of this hypothesis is warranted. Thus we turn to the analysis of the influence of environmental regulation on ICT and R&D capital accumulation to investigate for the presence of an indirect channel trough which environmental stringency affect productivity growth.

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[15] The choice of the time span is due to homogeneous data availability.

[16] The two most widely used panel data models are the random effect model (REM) and fixed effect model (FEM): both can control for heterogeneity. Their assumptions are different. REM models require that unobserved bilateral effects are ~ n.i.i. and orthogonal to the remaining part of the error term. regressors have to be uncorrelated to individual effects and error term for all cross sections and time periods. If the orthogonality conditions hold, the REM provides more efficient estimates than FE estimators. If explanatory variables are correlated with unobserved individual effects FEM is consistent.

[17] See Biagi, (2013) for a survey of the empirical literature on ICT and productivity.

[Table 2]

Table 3 , shows that environmental stringency measures at time t-1 positively affect ICT capital accumulation and that the closer the emission target (tgemiss) the faster is the rate of growth of ICT capital stock. Here we also check for a possible effect from an environmental patent variable (envpatent) that is statistically and positively correlated with ICT.

[Table 3]

We tested also the impacts of environmental measures on R&D (table 4). Besides the distance from the emission target that is not statistically significant, the other environmental policy indicators are all statistically significant with a positive sign. Results in tables 3 and 4 corroborate the idea that the NVPH cannot be rejected and that a deeper analysis of the channels through which environmental policy affect economic growth is needed.

[Table 4]

Thus in Table 5 we look for the joint impact of ICT and environmental stringency on productivity growth.

[Table 5]

Interestingly our estimates show a joint positive and statistically significant impact of ICT and Kyoto agreement dummy. The assumption is that those countries that are relatively more ICT intensive have higher productivity returns from the commitment to the Kyoto agreement.

5. Final thoughts and open questions

The primary purpose of this paper is to investigate the relationship between stringency of environmental policy regarding climate change and innovativeness and productivity for a panel of EU countries over the period 1995-2008. We have considered several ways of measuring environmental policy strictness. In particular we differentiated between command and control and marked based regulations in order to test whether they had a different impact on innovativeness and productivity.

Our preliminary results show that we cannot reject the narrow Porter Hypothesis. Interestingly enough it seems that the environmental stringency measures, in the period 1995-2008, on average did not erode competitiveness in EU members but stimulated innovations and productivity overcompensating for the costs of complying with these policies. As for the impact of the different policy instruments at this preliminary stage of the analysis no differences of impact between command and control and marked based policies emerge.

Accordingly to our estimates a double dividend might be at work in the European economies. This result could have important policy implications for the future environmental agreements negotiations not only at European level, in a moment in which the environmental issues have a central role in the economic policies at World level.

We intend to improve our analysis investigating further the effects of different environmental stringency instruments and details of instrument design, exploiting cross-country variation and the complementary use of different levels of data aggregation.

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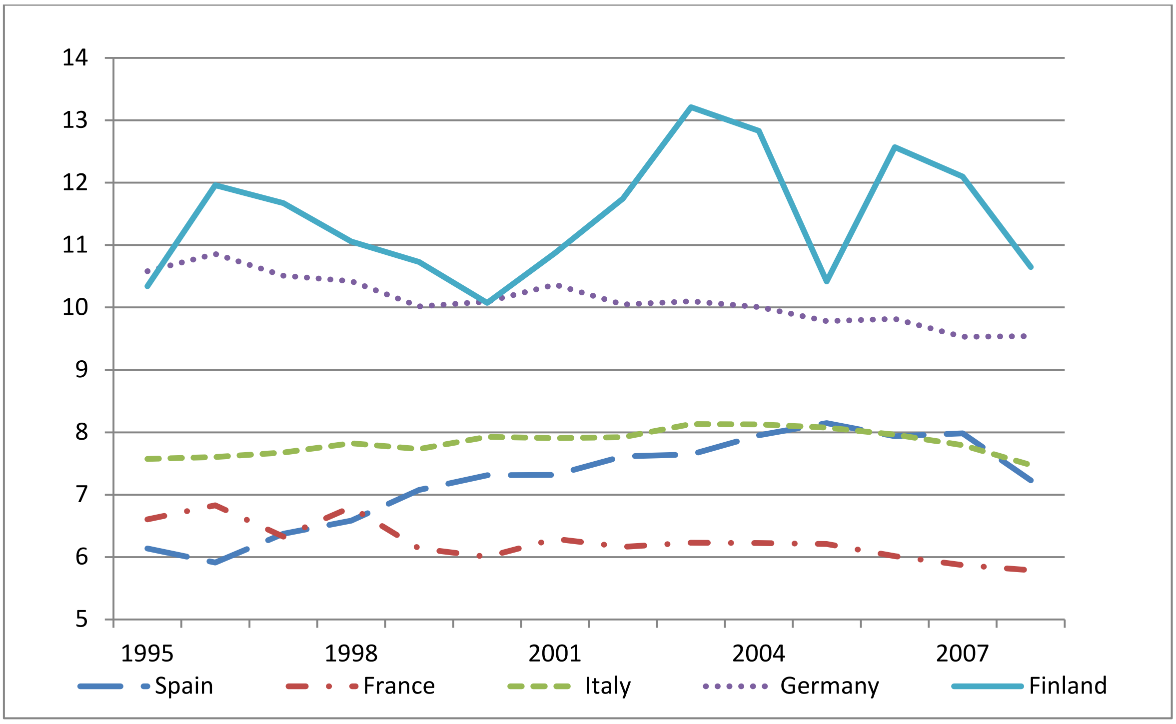
Appendix

Table 1 - Overview of empirical studies at macro level

Auth., year	Dep. Var.	Indep. Var.	Sample	Methodology	Result
Lanjouw and Mody (1996)	Patent counts	PACE	US, Japanese and German economies, 1971 - 1988	evaluate effect of pollution abatement capital expenditure on patent count with simple time series correlation	positive effect on patent count, but lagged by 1-2 years • evidence is found that foreign regulations also influence domestic patent count
Jeon and Sickles (2004)	Δ Efficiency score derived from DEA	CO2 emissions	17 OECD and 11 Asian economies, 1980 - 1995	compares efficiency scores of three scenarios (free emission, no change of emission levels, partial reduction of emissions)	adjusted TFP growth is lower than traditional for OECD countries whereas it is higher for ASEAN countries □productivity growth is lower in constant emission scenario then in free emissions scenario for OECD and ASEAN economies □□productivity growth is higher in scenario of emission reduction in OECD and ASEAN economies
De Vries and Withagen (2005)	Environmental patents	Dummy variable for regulations	14 OECD economies, 1970 - 2000	instrumental variable approach □fixed effect estimation	large positive effect on patent count
Yörük and Zaim (2005)	Δ Efficiency score derived from DEA (CO2, NOX and water pollutants)	UNFCCC protocol ratification	OECD economies, 1983- 1998	compares traditional with adjusted productivity index (emission reduction scenario) □fixed effect regression of dummy marking years of UNFCCC ratification on adjusted productivity growth	adjusted productivity growth is significantly larger than traditional □effect of NOX and water pollutants is largest □significant positive effect of UNFCCC ratification non adjusted MFP growth (no effect on traditional MFP growth)
Popp (2006)	Environmental patents	SOX and NOX regulations	US, Japanese and German economies, 1967 - 2003	evaluates effect of domestic and foreign regulation on innovation with simple time-series correlation	inventors respond to environmental regulation pressure in their own country but not to foreign environmental regulation
Johnstone et al. 2010a	Patent counts in renewable energy sectors	Renewable energy policy variables	25 OECD countries, 1978 - 2003	panel estimated with a negative binomial model, □fixed effects are included, □3 of 6 policy variables are modelled with dummies (introduced or not	renewable energy policies have a significant effect on related patents, □feed-in-tariffs have an additional positive effect on solar power patents, renewable energy certificates have a positive effect on wind energy patents.
Johnstone et al. 2010b	Environmental patent counts	Perceptions of environmental policy stringency, flexibility and predictability (WEF survey)	OECD countries, 2000 - 2007	panel estimated with a negative binomial model, □due to high collinearity of the policy variables, orthogonal factors are extracted, □no fixed effects are included	policy stringency, flexibility and stability have a positive coefficient (weak PH).
Albrizio et al (2014)	MFP	new environmental policy stringency (EPS) index,	19 OECD countries 1990-2012	panel □fixed effect estimation	On average, there is a positive effect of a tightening of environmental policy on MFP growth. The effect is more significant when controlling for covariates.

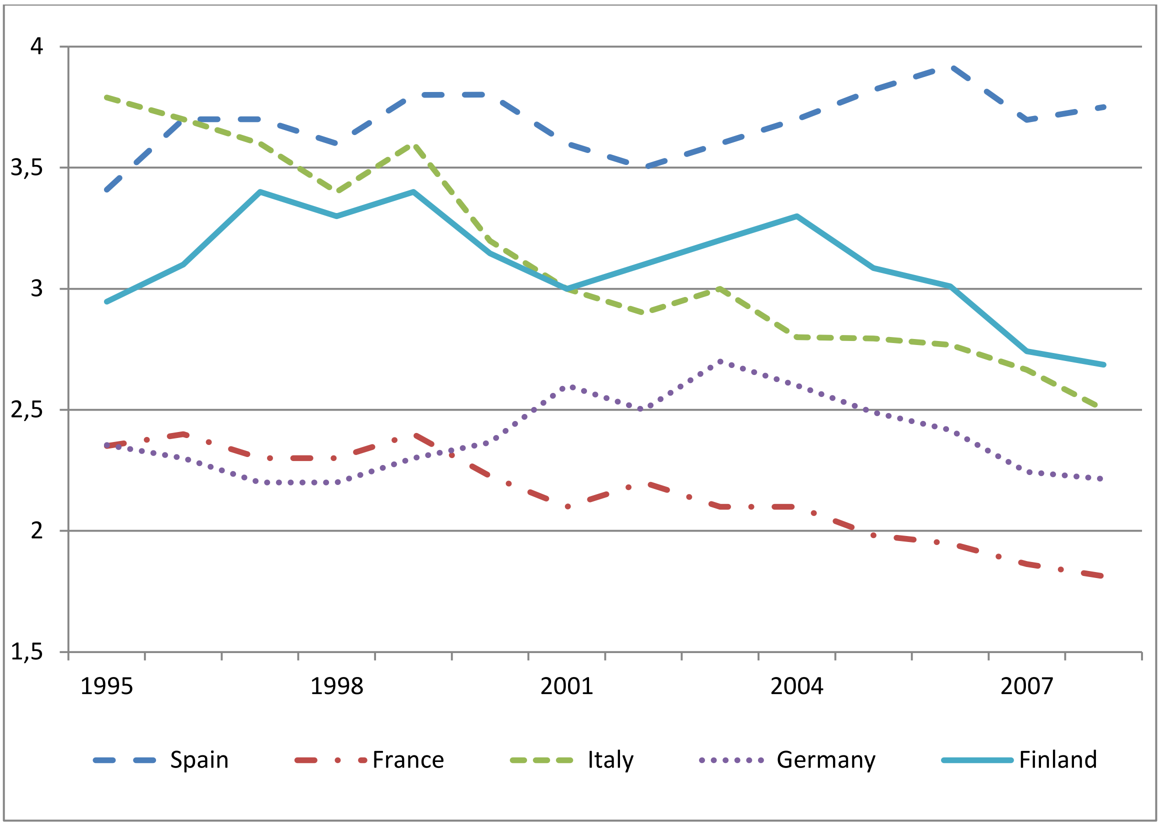
Source: Kozluk T and V. Zipperer, (2014).

Chart 1 - Emission of CO2 (metric tons per capita)



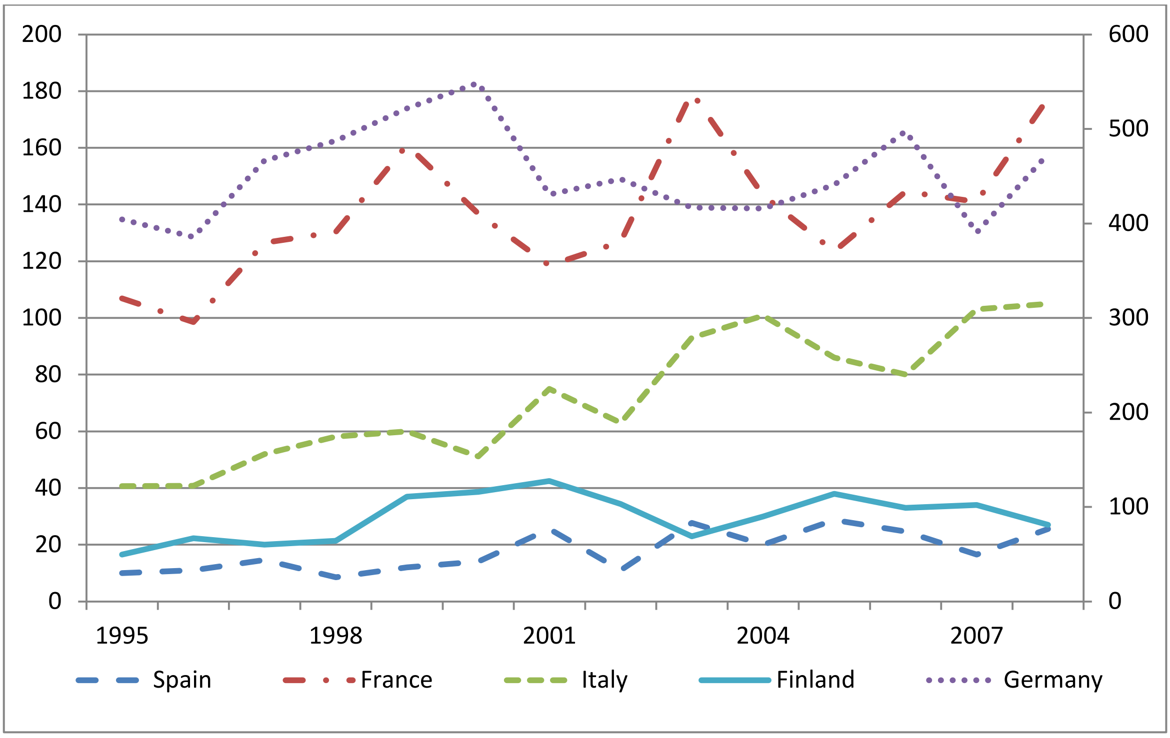
Source: OECD

Chart 2 - Environmental taxes (%GDP)



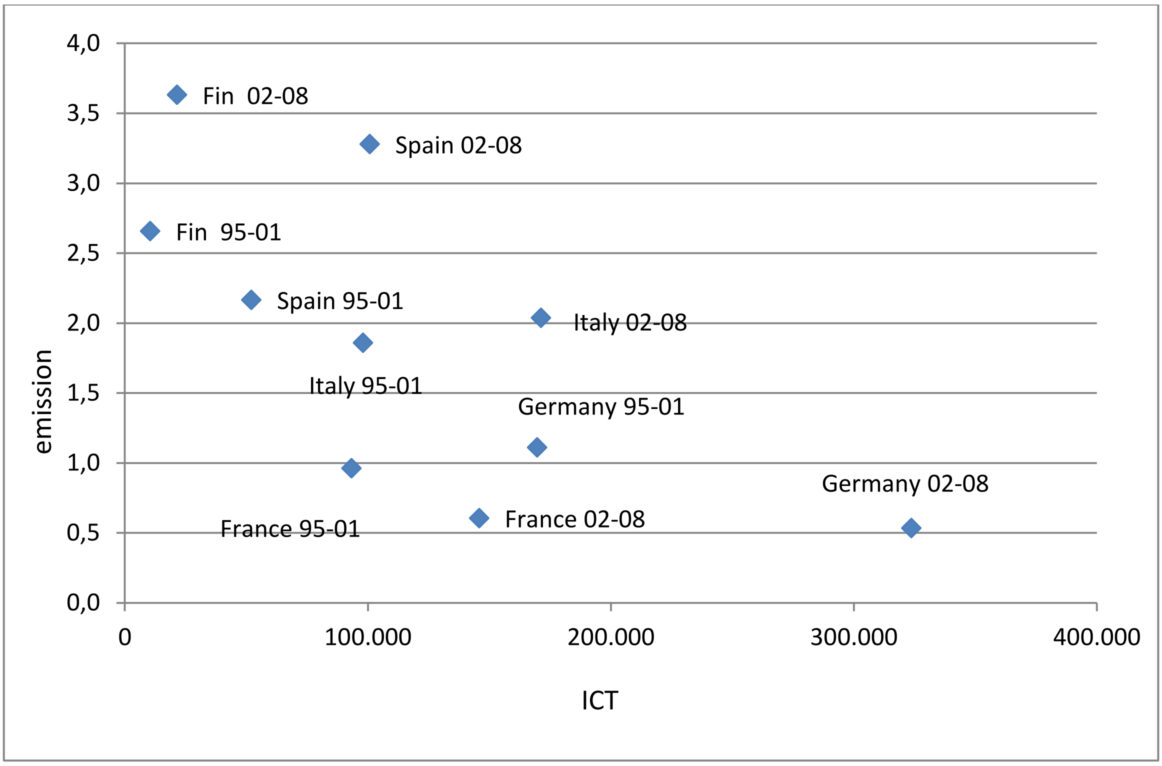
Source: OECD

Chart 3 - Environmental patents (application to the EPO, priority date)



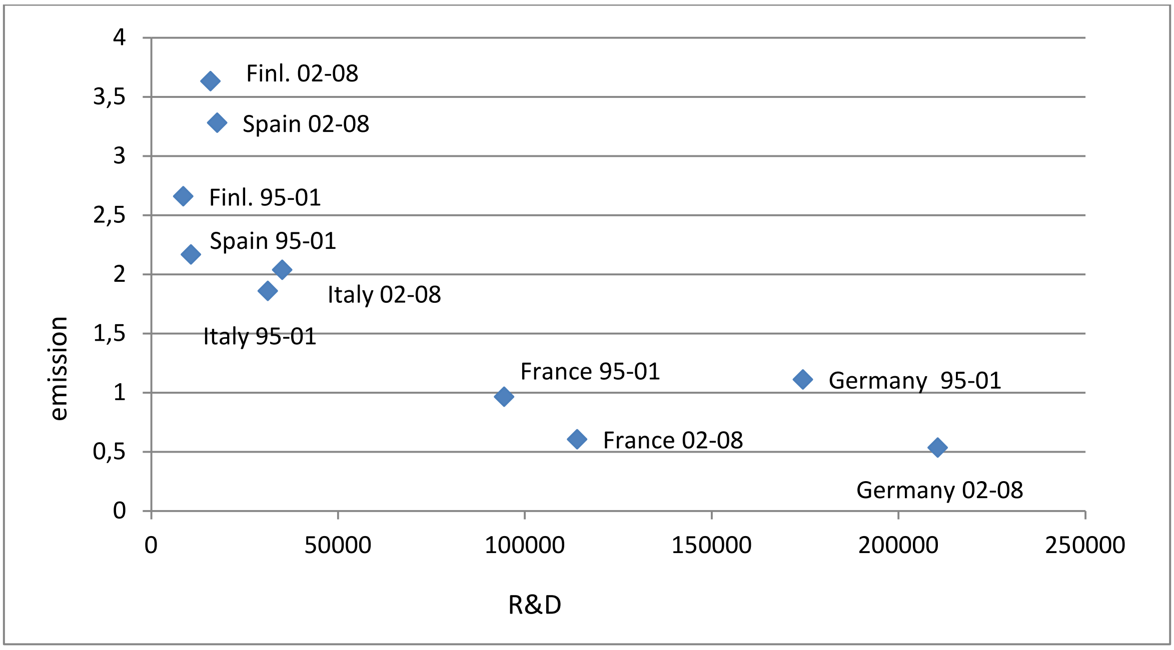
Source: OECD

Chart 4 - Distance from the emission target 2020 and ICT capital 1995-2008



Source: OECD and EU Klems

Chart 5 - Distance from the emission target 2020 and R&D expenditure 1995-2008



Source: OECD and Eurostat

Table 2 - Labor market productivity and environmental stringency

	(1)	(2)
	testing all var	testing all var
DlnNON-ICT	0.396***	0.396**
	(0.121)	(0.135)
DlnICT	0.0989***	0.0946**
	(0.0283)	(0.0303)
ets	-0.000608	
	(0.00271)	
L.envtaxes	0.0107	0.0108
	(0.00593)	(0.00633)
L.kyoto	0.00604*	0.00534**
	(0.00292)	(0.00190)
L.tgemiss		0.00106
		(0.00101)
Constant	-0.0278	-0.0298
	(0.0185)	(0.0201)
Observations	132	132
R-squared	0.252	0.254
Number of ctrycode	11	11

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3 - ICT and environmental stringency

	(1) testing all var	(2) testing all var
L.tgemiss	-0.138**	
	(0.0440)	
L.envtaxes	0.381**	0.400**
	(0.159)	(0.172)
L.envpatent	0.00483***	0.00472***
	(0.000949)	(0.000842)
L.kyoto	0.682***	0.549***
	(0.0522)	(0.0568)
ets		0.192***
		(0.0274)
Constant	0.332	0.0141
	(0.488)	(0.520)
Observations	143	143
R-squared	0.658	0.642
Number of ctrycode	11	11

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4 - R&D and environmental stringency

	(1) testing all var	(2) testing all var
ets	0.0747***	
	(0.0206)	
L.envtaxes	0.287***	0.299***
	(0.0523)	(0.0456)
L.envpatent	0.00109***	0.00106***
	(0.000262)	(0.000228)
L.kyoto	0.231***	
	(0.0301)	
L.tgemiss		0.00401
		(0.0173)
L.kyoto		0.282***
		(0.0372)
Constant	0.288	0.226
	(0.175)	(0.166)
Observations	156	156
R-squared	0.658	0.693
Number of ctrycode	12	12

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5 – ICT and environmental policies interactions

	(1)	(2)
	testing all var	testing all var
DlnNON-ICT	0.425***	0.413***
	(0.125)	(0.127)
DlnICT	0.0825*	0.0852**
	(0.0380)	(0.0361)
lnICT	-0.00715	-0.00807**
	(0.00435)	(0.00324)
L.tgemiss	0.000862	0.000410
	(0.00124)	(0.00149)
ets	0.00109	0.00120
	(0.00307)	(0.00315)
L.envtaxes	0.0117*	0.0114
	(0.00598)	(0.00753)
L.kyoto	0.00233	0.00832**
	(0.00471)	(0.00363)
L.ICT_ky_l	0.00272**	
	(0.00122)	
ICT_entx_l		0.000527
		(0.00160)
Constant	-0.0177	-0.0174
	(0.0187)	(0.0196)
Observations	132	132
R-squared	0.282	0.271
Number of ctrycode	11	11

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6 - Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Labourprod	192	3.79	0.87	2.78	5.88
lnNON-ICT	143	4.20	0.98	2.86	6.29
lnICT	143	2.02	1.12	0.39	5.18
ets	492	0.13	0.34	0	1
envtaxes	204	2.82	0.92	0.8	5.2
kyoto	492	0.20	0.40	0	1
tgemiss	251	1.91	1.11	-0.35	5.29
envpatent	312	110.53	146.76	1	586.8
Ln R&D	192	1.39	1.25	-0.71	4.43

Table 7 - Data description

Variable	Description	Source
Labour productivity	Real value added per hours worked	EUKLEMS
NON-ICT	Real capital stock	EUKLEMS
ICT	Real capital stock	EUKLEMS
R&D	Expenditure data	BERD Eurostat
ets	time dummy "2005" to catch the impact of the introduction of the European Emission Trading System	EU
envtaxes	the revenues from environmental taxes in percentage of GDP	OECD
kyoto	Ratification of the Kyoto agreement	UNFCC
tgemiss	CO2 emissions in metric tons per capita as a difference with respect to the 2020 target	OECD
envpatent	number of environmental patent applications to the EPO	OECD