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Environmental Policies, Innovation and Productivity in the EU

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Roberta De Santis* and Cecilia Jona Lasinio**

Abstract

In this paper we test the weak Porter hypothesis on a sample of European economies in the period 1995-2008. We focus on the channels through which tighter environmental regulation affects productivity and innovation. Our findings suggest that the "weak" Porter hypothesis cannot be rejected and that the choice of policy instruments is not neutral. In particular, market based environmental stringency measures seem to be the most suitable to stimulate innovation and productivity growth. Consistently with the strategic reorientation of environmental policies in the European Union since the end of the eighties, our results indicate that the EU might privilege market based instruments in order to meet more effectively the 2030 targets, especially through the channels of innovation and productivity enhancement.

Keywords: environmental regulation, productivity, innovation, Porter hypothesis

JEL Code: D24, Q50, Q55, O47, O31

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Roberta De Santis and Cecilia Jona Lasinio

Environmental Policies, Innovation and Productivity in the EU

Introduction

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. But, at the same time, more stringent environmental policies can stimulate innovations that may over-compensate for the costs of complying with these policies (Porter and Van der Linde 1995). This is known as the Porter hypothesis and it suggests the existence of a double dividend – environment and competition are not incompatible since properly designed environmental regulation can stimulate innovation which in turn will increase competitiveness.

The goal of inducing environmental innovation and enhancing productivity is a significant challenge to policymakers.[1] The European Union has been very sensitive and active in the design of environmental and climate regulation policies since the beginning of the 1970s. The European Commission can be identified as a motivating force in global environmental negotiations that strongly supported the achievement of the two United Nations climate

[1] Pollution is a negative environmental externality, while innovation is a positive externality. Therefore, without a public intervention to manage these two market failures, firms pollute too much and innovate too little compared with the social optimum. As such, investments and thus, innovation to develop "green" technology are likely to be below the social optimum because, for them, the two market failures are mutually reinforcing (Jaffe et al. 2005).

treaties: the UN Framework Convention on Climate Change (UNFCCC) in 1992 and the Kyoto Protocol in 1997.

The introduction of the EU Emission Trading Scheme (ETS) (Directive 2003/87/EC)[2] and the directives of the 2020 Climate and Energy Package on CO2 emission reduction (2009/29/EC, 2009) and renewable energy (2009/28/EC, 2009) are two of the most significant EU policy interventions. The EU ETS is a relevant commitment to the strategic reorientation of environmental policies in the European Union that took place gradually 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.[3]

In 2007, EU leaders endorsed an integrated approach to climate and energy policy and committed to transform Europe into a highly energy-efficient, low carbon economy. They made a unilateral commitment that Europe would cut its emissions by at least 20% compared to 1990 levels by 2020.

Recently, the European Commission approved new headline targets for 2030, reducing greenhouse gases emissions by at least 40% compared to the 1990

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[2] 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 commitment 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.

[3] Market-based instruments (MBI), such as emissions trading, aim at encouraging firm's behavior through market signals rather than through explicit directives concerning pollution control levels or methods. Command and control regulations (CCR), instead, set uniform standards for firms, that can be technology or performance based. In general, the mainstream neoclassical literature attributes to MBIs the property of static efficiency, saving information costs, the possibility of a double dividend, self-enforcement and the capability of promoting innovation better than command and control instruments.

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.

This paper investigates the channels through which tighter environmental regulation affect productivity and innovation. Our analysis is focused on a sample of European economies over the period 1995-2008. We contribute to the existing literature which evaluates the impact of environmental regulation on innovation and productivity by adopting a cross-country macroeconomic perspective. Moreover we distinguish between command and control and market based environmental policy instruments to examine whether environmental regulation has a differential effect on innovation and productivity.

The paper is organized as follows: section II provides some stylized facts about environmental policy in the European Union, section III describes the data set, the empirical model and the estimation strategy, section IV illustrates empirical findings. Conclusions follow.

II. Survey of recent empirical literature

Innovation is a core element 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 characteristics of the environmental policy framework can affect the rate and direction of innovation in pollution abatement technologies. This evidence stimulated a number of empirical studies to evaluate the role of environmental policy on technological innovation (Johnstone and Labonne, 2006).

Different policy measures are likely to have different impacts on innovation. There is a large body of literature suggesting that market based instruments are more likely to induce innovation than direct forms of regulation.[4]

However, empirical investigation of the consequences of environmental regulation at the macroeconomic level is rather scant, heterogeneous and mostly developed in the context of international trade.[5] Only few studies documented the effect of more stringent environmental regulation on productivity and environmental innovation adopting a cross-country perspective but the empirical evidence is fairly inconclusive.[6]

Most of the empirical studies developed so far take a microeconomic perspective.[7] Empirical findings are typically very context-specific and focused on different indicators of efficiency and innovation (e.g. multifactor productivity, patent counts or efficiency score). As a consequence, the size and the sign of the identified effects are hardly comparable.

[4] For a survey see Jaffe et al., 2002; Popp et al., 2009.
[5] De Santis (2013).
[6] See table A1 in the appendix.
[7] See Koźluk and Zipperer, 2014.

Further, the 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 'narrow' 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 expenditure and pollution abatement costs and find a positive correlation.

In a recent paper, Albrizio et al (2014) look at the effect of environmental stringency policy changes on productivity growth in the 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 environmental policy measures varies with industry pollution intensity and technological advancement. Their results suggest 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*".[8]

III. Equation, data set and econometric strategy

The Porter assumption has been empirically examined by evaluating two different degrees of stringency: the weak and the strong version of the Porter hypothesis (Jaffe and Palmer, 1997).[9]. In this paper we test the weak

[8] Albrizio et al (2014).
9 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

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 a 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 and innovation intensity were relatively higher experienced faster productivity growth.

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:

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.

$$\Delta \ln Y = \alpha_1 + \alpha_2 \Delta \ln X + \alpha_3 Z_1 + \alpha_4 Z_2\ \varepsilon \quad (1)$$

Where *Y* is an indicator of labor productivity (*LP or MFP) X* is a set of controls including measures of capital stock and Z_1 is a measure of environmental regulation. If α_3 is positive then our assumption (the Weak Version of the Porter Hypothesis WVPH 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 checking for the presence of spillovers to environmental stringency measures. Z_2 is a vector of control variables including output gap, real oil price, trade openness, government balance, FDI inflows and a time trend.[10]

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.

$$\Delta \ln K^i = \alpha_1 + \alpha_2 \ln Z_1 + \alpha_3 Z_2\ \varepsilon \quad (2)$$

If α_2 is positive and significant we can take the results as an "indirect" test of WVPH.

[10] See table A2 in the appendix for a description of the variables.

As for environmental stringency indicators, it is relevant to notice that policy makers have the power of choosing between alternative policy instruments, and that their choice is strongly influenced by the degree of incentives to develop environmental friendly technologies. In particular, there are two main categories of policy instruments: i) market-based instruments providing incentives to the reduction or removal of negative environmental externalities and ii) command and control instruments that are more strict compared to market-based instruments (i.e. emission standards, process/equipment specifications, limits on input/output/discharges).[11]

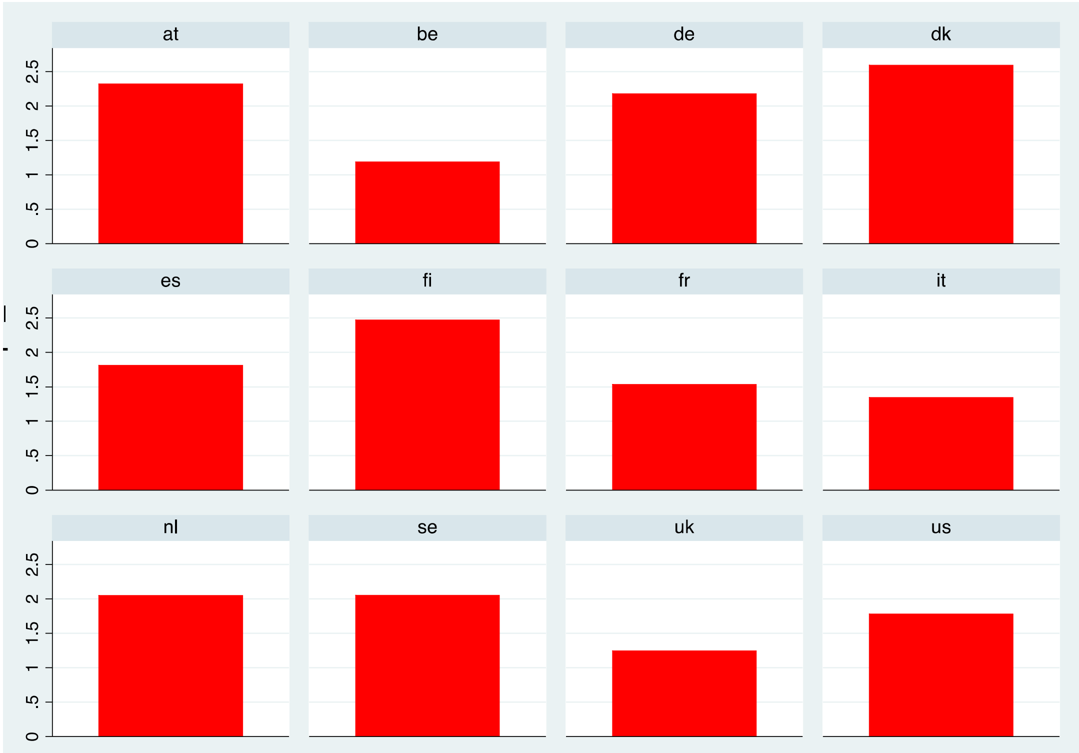
We initially evaluate the direct and indirect effect of the new Environmental Policy Stringency (EPS) index, developed for the OECD countries by Botta and Koźluk (2014), on productivity growth. The EPS is a composite indicator based on the aggregation of quantitative and qualitative information on selected environmental policy instruments into one comparable, country-specific proxy of environmental policy stringency.[12]

The EPS covers 24 OECD countries over the period 1990-2012, and it is particularly useful for our macroeconomic, cross country approach since it reduces a complex of multidimensional policies into a comparable country-specific measure.

[11] The environmental economics literature has broadly discussed the incentives for the adoption and development of environment-friendly technologies provided by different policy instruments. The debate was in fact dominated by the opposition between command-and-control versus economic and market driven approach, the first being considered inferior compared to the second. See Malueg (1989) and Fisher et al. (2003)

[12] The indicator is based on the taxonomy developed by De Serres et al. (2010) and the sub-components are all weighted equally. A market-based subcomponent groups instruments which assign an explicit price to the externalities (taxes: CO2, SOX, NOX, and diesel fuel; trading schemes: CO2, renewable energy certificates, energy efficiency certificates; feed in- tariffs; and deposit-refund-schemes), while the non-market component clusters command-and-control instruments, such as standards (emission limit values for NOX, SOX, and PM, limits on sulphur content in diesel), and technology-support policies, such as government R&D subsidies.

Chart 1. Environmental Policy Stringency Indicator (EPS)



Source: Albrizio 2014.

Then we test four different measures of environmental regulation that can be considered "EU specific". They include command and control (i and ii) and marked based provisions (iii)[13]: i) CO^2 emissions in metric tons per capita as a difference with respect to the 2020 target,[14] ii) the ratification of the Kyoto agreement and iii) the revenues from environmental taxes in percentage of GDP[15] and iv) a dummy "2005" to catch the impact of the introduction of the European Emission Trading System (ETS).

We included both types of environmental regulation since related literature supports the assumption that the impact of marked based and command and control policy instruments on innovation and productivity can differ. In

[13] 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.
[14] A 20% reduction in EU greenhouse gas emissions from 1990 levels.
[15] On the whole, most European countries have fairly high levels of environmental taxation – at least compared to the other OECD countries.

particular, command and control measures have been criticized for restricting technological progress since they do not provide any incentive to innovate.[16] 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 about the technological solution to minimize compliance costs.

All in all, we expect a positive coefficient for the control variables and ICT and R&D capital stock. But we do not have any a priori about the expected sign of environmental variables in both equations. A positive sign of ETS, Kyoto agreement, environmental taxes and a negative coefficient for the variable representing the distance of the emission with respect to the EU target however would support the WVPH hypothesis.

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

$$\Delta \ln Y = \alpha_1 + \alpha_2 \Delta \ln X + \alpha_3 \ln K_I{*}Z_1 + \varepsilon \qquad (3)$$

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.

[16] Swaney (1992), Fischer, Parry and Pizer (2003), Jaffe and Palmer (1997).

Our analysis covers 11 EU countries (Austria, Belgium, Germany, Denmark, Spain, Finland, France, Italy, The Netherlands, Sweden, UK, plus USA as a control country) over the period 1995-2008.[17] Annual data are from OECD and EUKLEMS (see for descriptive statistics table 5). 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 a Hausman specification test to check the presence of correlation between explanatory variables and individual effects.

Equation (1) can be affected by endogeneity and we control measurement errors by means of instrumental variables.

IV. Estimation results: is there a double dividend?

Table 1[18] shows the estimation results for equation (1) a production function augmented with environmental policy variables to check for the direct impact of environmental regulation on productivity growth. We run fixed effects (columns 1 and 2) and instrumental variables regressions (columns 3 and 4). Coherently with the empirical production function literature,[19] ICT and NON ICT capital coefficients are positive and statistically significant. As for the EPS index, in line with Albrizio 2014, we find a positive and significant coefficient and the results in columns 2 and 4 suggest that the positive relationship between labor productivity and environmental policy stringency is mainly

[17] The choice of the time span is due to homogeneous data availability furthermore we decided to exclude from the analysis the period of the sovereign and financial crisis that somehow could bias the results.

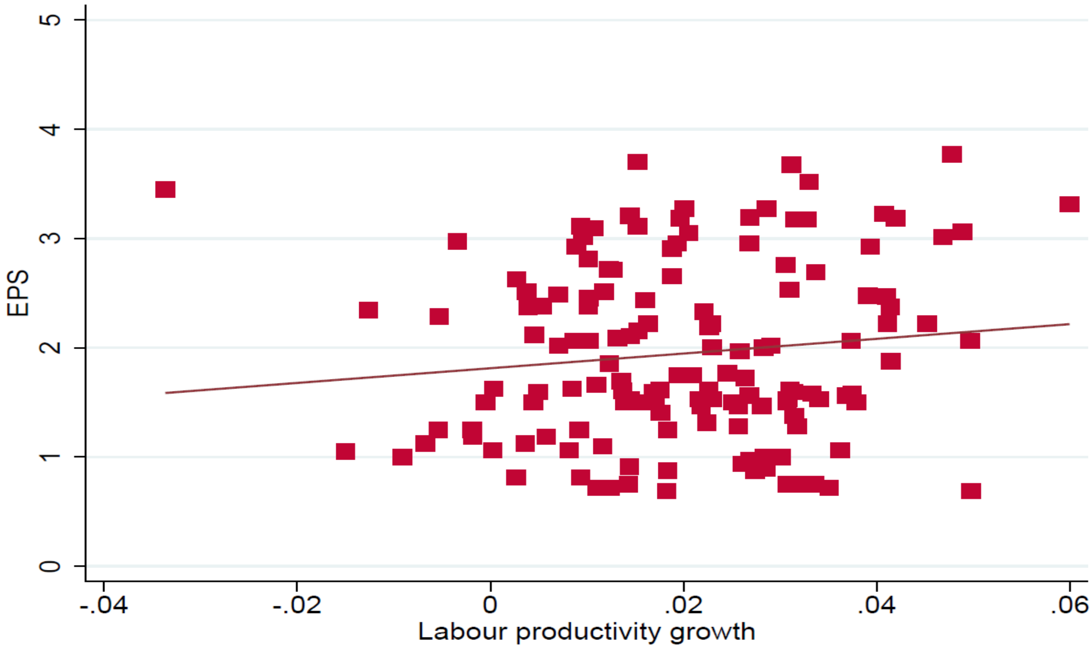
[18] In Table 2 labor productivity and EPS and table 5 MFP and EPS and EU provisions refer to equation 1, table 2 ICT, R&D and EPS and table 4 ICT, R&D and “European” environmental provisions refers to equation 2 and table 3 labor productivity and “European” environmental provisions refers to equation 2 and 3,

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

driven by the market based component of the composite indicator (eps_mb) (see Chart 2). Policy stringency indicators are lagged since the productivity effects of policy changes might be lagged in time.

The findings in Table 1 suggest that the WVPH cannot be rejected (α_3 is positive and significant) and that a deeper investigation of this hypothesis is warranted. Thus we turn to the analysis of the influence of environmental regulation, as measured by the OECD composite indicators, on ICT capital accumulation and R&D expenditure to investigate for the presence of an indirect channel trough which environmental stringency might affect productivity growth (cfr equation 2).

Chart 2. EPS vs. labour productivity growth: 1995-2008



Source: OECD

Table 1. Labour productivity and EPS

	(1)	(2)	(3)	(4)
VARIABLES	FE		IV	
DlnH_k_nonict_klems	0.426***	0.431***	0.528***	0.532***
	(0.0840)	(0.0838)	(0.106)	(0.100)
DlnH_k_ict_klems	0.111***	0.106***	0.0830**	0.0717**
	(0.0295)	(0.0296)	(0.0323)	(0.0320)
L.eps_fs	0.00754***		0.00805***	
	(0.00272)		(0.00237)	
Trend	0.00119*	0.00108	-9.27e-06	-0.000249
	(0.000716)	(0.000719)	(0.000609)	(0.000618)
L.outputgap	-0.00410***	-0.00388***	-0.00506***	-0.00466***
	(0.000792)	(0.000808)	(0.000699)	(0.000741)
L.eps_mb		0.00565***		0.00623***
		(0.00197)		(0.00166)
L.eps_nmb		0.00196		0.00199
		(0.00194)		(0.00166)
L.realoilp	-0.000145*	-0.000147*		
	(0.000716)	(0.000018)		
Constant	-0.0389*	-0.0342*	-0.00525	0.00327
	(0.0199)	(0.0202)	(0.0187)	(0.0191)
Observations	132	132	121	121
R-squared	0.423	0.431	0.640	0.647
Hausman test (⍰⍰)	1.89 (0.08)	12.7 (0.05)		
Standard errors in parentheses				
*** p<0.01, ** p<0.05, * p<0.1				

Table 2 confirms previous results (α_2 is positive and significant) showing that "marked based" environmental stringency measures (eps_mb) positively affect ICT capital accumulation and R&D expenditure. Interestingly, command and control (eps_nmb) environmental measures have a significant negative impact on R&D. One possible explanation is that there is a mechanism at work for which the costs of complying with environmental provision on average offset R&D expenditure.

However this result deserves careful consideration since our specification might not capture all relevant market interactions.

Table 2. ICT, R&D and EPS

FE	(1)	(2)
	ICT	R&D
eps_mb	0.014**	0.006**
	(0.006)	(0.003)
eps_nmb	-0.006	-0.008***
	(0.006)	(0.003)
realoilp	-0.0004*	-0.0004***
	(0.0002)	(0.0001)
outputgap	0.013***	-0.001
	(0.002)	(0.001)
trend	-0.007***	0.003***
	(0.002)	(0.001)
Constant	0.334***	-0.032
	(0.053)	(0.028)
Observations	132	144
R-squared	0.433	0.223
Number of ctrycode	11	12
Hausman test (χ^2)	4.08 (0.54)	41.3 (0.00)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In what follows, we look at the direct and indirect impact of individual environmental "European" provisions on growth. The sole provisions positively and significantly affecting labor productivity are marked based: environmental taxes (envtaxes) and the introduction of the ETS in 2005. Particularly the coefficient of the environmental taxes is the highest. Command and control indicators (i.e. Kyoto and Emission targets) are in most cases not statistically significant (see Table 3).

The inclusion of an interaction term between the policy indicators and capital stocks provides additional insights to the analysis (cfr equation 3). With the inclusion of these terms, the estimated coefficients indicate the difference in effects of the variable (ICT) on the dependent variable (Labour productivity) after and before the introduction of the ETS.

The synergy between ETS and ICT is positive and statistically significant (α_3 is positive and significant) corroborating the assumption that those countries that are relatively more ICT intensive had higher productivity returns from the introduction of the ETS. Interestingly also the interaction between ICT and Kyoto is positive and significant. Being more ICT intensive mitigates (by the amount of the estimated coefficient) the negative impact of the Kyoto agreement on productivity.

The positive effect of EU environmental measures is robust also when we look at ICT capital accumulation (Table 4 cfr equation 2), in particular we find that the ratification of the Kyoto agreement had a negative and significant influence while the emission target had a positive and significant impact. As for R&D both Kyoto and ETS had a negative and significant impact showing once again that the impact of environmental policies on R&D is somehow difficult to catch at least at aggregate level.

Table 3. Labor productivity and "European" environmental provisions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	No iteractions		ICT and Env Taxes		ICT and Emissions		ICT and ETS		ICT and Kyoto	
VARIABLES	FE	IV	FE	IV	FE	IV	FE	IV	FE	IV
DlnH_k_nonict_klems	0.495***	0.543***	0.465***	0.465***	0.424***	0.415***	0.509***	0.508***	0.456***	0.407***
	(0.0872)	(0.107)	(0.0844)	(0.0992)	(0.0837)	(0.108)	(0.0933)	(0.115)	(0.0822)	(0.106)
DlnH_k_ict_klems	0.105***	0.102***	0.262***	0.131***	0.119***	0.123***	0.102***	0.110***	0.127***	0.142***
	(0.0322)	(0.0304)	(0.0693)	(0.0490)	(0.0361)	(0.0405)	(0.0361)	(0.0393)	(0.0321)	(0.0322)
L.ets	0.00751**	0.0126***	0.00629*	0.0116***						
	(0.00377)	(0.00364)	(0.00363)	(0.00359)						
L.tgemiss	0.000191	-0.000851			-0.00154	-0.000749				
	(0.00170)	(0.00164)			(0.00232)	(0.00188)				
L.envtaxes	0.0133**	0.0125**	0.0179***	0.0153***						
	(0.00549)	(0.00504)	(0.00562)	(0.00525)						
L.kyoto	-0.00200	-0.00260							-0.0122*	-0.00896
	(0.00433)	(0.00338)							(0.00664)	(0.00585)
L.outputgap	-0.00421***	-0.00464***	-0.00378***	-0.00406***	-0.00496***	-0.00505***	-0.00481***	-0.00478***	-0.00480***	-0.00460***
	(0.000967)	(0.000815)	(0.000796)	(0.000710)	(0.000910)	(0.000772)	(0.000879)	(0.000766)	(0.000967)	(0.000882)
L.tradeopen	-0.000525**	-0.000704***	-0.000674***	-0.000650***	-0.000274	-0.000436*	-0.000379	-0.000503**	-0.000325	-0.000443**
	(0.000239)	(0.000226)	(0.000235)	(0.000205)	(0.000242)	(0.000237)	(0.000241)	(0.000220)	(0.000219)	(0.000224)
trend	0.00196**	0.00200***	0.00195***	0.00134***	0.00186***	0.00222***	0.00131*	0.00162**	0.00282**	0.000654
	(0.000760)	(0.000694)	(0.000521)	(0.000497)	(0.000600)	(0.000526)	(0.000739)	(0.000798)	(0.00135)	(0.00131)
Dict_envtaxes			-0.0522**	-0.0199						
			(0.0211)	(0.0157)						
L.Dict_envtaxes										
L.Dict_tgemiss					0.00645	0.00846				
					(0.0135)	(0.01000)				
ets							-0.00136	-0.000129		
							(0.00409)	(0.00355)		
L.Dict_ets							0.0946**	0.0933**		
							(0.0458)	(0.0394)		
L.lnH_k_ict_klems									-0.00451	0.00958
									(0.00875)	(0.00895)
L.ict_kyoto									0.00427**	0.00519***
									(0.00187)	(0.00192)
Constant	-0.0618**	-0.0224	-0.0648***	-0.0138	-0.0341*	-0.0252	-0.0105	0.00173	-0.0555*	0.00918
	(0.0250)	(0.0248)	(0.0197)	(0.0205)	(0.0188)	(0.0186)	(0.0254)	(0.0247)	(0.0292)	(0.0318)
Observations	132	121	132	121	121	121	121	121	132	121
R-squared	0.429	0.648	0.457	1	0.414	0.622	0.436	0.635	0.413	0.640
Hausman test (^{2})	10.52 (0.31)		13.4 (0.00)		10.52 (0.31)		6.78 (0.56)		3.88 (0.87)	

Standard errors in parentheses

***** p<0.01, ** p<0.05, * p<0.1**

Table 4. ICT, R&D and "European" environmental provisions

	(1)	(2)
FE	ICT	R&D
L.tgemiss	0.010*	0.003
	(0.005)	(0.003)
L.envtaxes	0.031**	0.004
	(0.015)	(0.009)
L.kyoto	-0.040***	-0.012**
	(0.011)	(0.006)
ets	0.023**	-0.014***
	(0.010)	(0.005)
L.tradeopen	0.001	-0.001*
	(0.001)	(0.0003)
trend	-0.004**	0.003***
	(0.002)	(0.001)
Constant	0.082	-0.018
	(0.063)	(0.034)
Observations	132	144
R-squared	0.418	0.161
Number of ctrycode	11	12
Hausman test (χ^2)	4.12 (0.66)	2.71 (0.85)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Finally we investigate the relationship between a measure of Total Factor Productivity growth and our environmental policy indicators (cfr equation 1).

According to our estimates, multifactor productivity is positively and significantly affected by EPS, probably because of the positive influence of market based policy measures on growth (table 5). The introduction of the European trading system has a positive impact on productivity too. This result supports the idea that the introduction of a "cap and trade" provision is an effective incentive to the country to reduce pollution thus stimulating innovation.

Table 5. MFP and EPS and EU provisions

FE	(1)	(2)	(3)	(4)	(5)	(6)
eps_fs	0.383**					
	(0.179)					
outputgap	0.0974**		0.104**		0.143**	
	(0.0456)		(0.0476)		(0.0596)	
Trend	-0.112***	-0.0593*	-0.113***	-0.0630*	-0.135***	0.0278
	(0.0349)	(0.0317)	(0.0352)	(0.0320)	(0.0495)	(0.0459)
L.eps_fs		0.409**				
		(0.164)				
L.outputgap		-0.0971*		-0.0896*		-0.138**
		(0.0519)		(0.0528)		(0.0592)
eps_mb			0.241*			
			(0.132)			
eps_nmb			0.145			
			(0.127)			
L.eps_mb				0.284**		
				(0.126)		
L.eps_nmb				0.134		
				(0.119)		
Ets					0.129	
					(0.227)	
tgemiss					-0.0675	
					(0.111)	
envtaxes					0.283	
					(0.397)	
Kyoto					0.542*	
					(0.303)	
tradeopen					0.00160	
					(0.0151)	
L.ets						0.736***
						(0.218)
L.tgemiss						0.0976
						(0.113)
L.envtaxes						0.732**
						(0.317)
L.kyoto						-0.228
						(0.270)
L.tradeopen						-0.0235
						(0.0145)
Constant	2.878***	1.249	2.954***	1.393*	3.304*	-1.344
	(0.858)	(0.817)	(0.874)	(0.837)	(1.690)	(1.423)
Observations	123	123	123	123	123	123
R-squared	0.093	0.111	0.095	0.116	0.093	0.184
Number of ctrycode	12	12	12	12	12	12

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Conclusion

In this paper we explore the relationship between environmental policy stringency, productivity and innovation for a panel of EU countries over the period 1995-2008. We test for the effect of several measures of environmental policy stringency on productivity and its components.

Our findings support the assumption that restrictive environmental policies did not erode the competitiveness in the EU member economies but instead had a growth-promoting effect. Market based provisions (i.e. ETS, environmental taxes), in particular, had a positive impact on productivity growth via their influence on ICT capital accumulation. Environmental taxes had the largest impact on labour productivity and ICT capital accumulation.

On the other hand, command and control policy measures did not appear to have a statistically significant impact on the countries' growth performances. The ratification of the Kyoto agreement is the sole exception negatively affecting ICT capital accumulation and R&D expenditure. However, the interaction between ICT and Kyoto is positive and significant supporting the idea that the negative impact on productivity determined by the Kyoto agreement is mitigated by the ICT intensity.

Country-level analysis allowed us to capture the variation both across policies and across outcomes, as well as possible spillover effects. Compared to industry or firm level studies, which suffer from the lack of generality as they usually provide very context-specific conclusions, a country-level approach is best suited for international policy-making.

Our analysis corroborates the assumption that the gradual strategic reorientation of environmental policies in the EU in favor of economic incentives in the period under examination has been more effective in stimulating productivity and innovation than setting explicit directives about pollution control levels or methods. This evidence supports the conjecture that the stringency of environmental policies can be increased without harming economy-wide productivity and that a deeper analysis of the mechanisms through which environmental policy influenced productivity and innovativeness has potentially relevant implication to develop further the European environmental policy agenda. Consistently with the strategic reorientation of environmental policies in the European Union since the end of the 1980s, our results indicate that the EU might privilege the market based instruments in order to meet more effectively the 2030 targets especially through the channels of innovation and productivity enhancement.

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Appendix

Table A1. 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)	ΔEfficiency score derived from DEA	CO_2 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 (CO_2, 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. 2010°	Patent counts in renewable	Renewable energy policy	25 OECD countries, 1978 –	panel estimated with a negative binomial model,	renewable energy policies have a significant effect on

	energy sectors	variables	2003	fixed effects are included, 3 of 6 policy variables are modelled with dummies (introduced or not	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.

Table A2. Descriptive statistics

Variable	Obs	Mean Std. Dev.	Min	Max
lnLP	192	3.791522 .8746021	2.783899	5.882199
lnnonICTK	143	4.20087 .9831938	2.869709	6.299414
lnICTK	143	2.025613 1.125143	0.3929425	5.184725
lnR&D	192	1.398369 1.25344	-0.7112087	4.436729
outputgap	306	.1046405 2.33713	-7.97	6.98
realoilp	372	-135.9265 1051.201	-5877.109	152.3371
eps_mb	252	1.507887 1.04151	0.125	4.1
eps_nmb	250	2.25 1.13541	0.75	5.5
eps_fs	250	1.88385 .9680698	0.5	4.675
envtaxes	204	2.820098 .9258935	0.8	5.2
envpatent	312	110.5359 146.7683	1	586.8
ets	492	.1341463 .3411564	0	1
tgemiss	251	1.915321 1.113396	-0.35757	5.293368
kyoto	492	.2012195 .4013198	0	1

Table A3. 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
Output gap	% deviation of GDP from its trend.	Source: OECD
Fiscal balance/GDP	Tax revenue minus any government spending.	Source: WDI World Bank
Real oil price in US$	Price of oil in US dollars.	Source: Thomson Reuters Datastream
Trade openness	Export +Import/2 in US dollars current prices	Source: OECD

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