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ENVIRONMENTAL POLICIES, INNOVATION AND PRODUCTIVITY IN EU

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***Abstract**. 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 environmental regulation. In this paper, we adopt a macroeconomic approach to investigate the impact of different environmental instruments on the economy as a whole. We investigate the environmental policy impacts on a sample of European economies in 1995-2008. Our findings suggest that the "narrow" Porter Hypothesis cannot be rejected and that the choice of the policy instruments is not neutral. In particular, market based environmental stringency measures look as the most effective to stimulate innovations and productivity..*

KEY WORDS: environmental regulation, productivity, innovation, Porter hypothesis

JEL N°: D24, Q50, Q55, O47, O31

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Introduction

> *"… 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. 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 that suggests the existence of a double dividend, that is 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 enhance productivity is a significant challenge to policymakers. 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 since the two market failures are mutually reinforcing (Jaffe et al. 2005).

Innovation is therefore 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.

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 [1]. Only few studies documented the effect of more stringent

1 R. De Santis (2013).

environmental regulation on productivity and environmental innovation adopting a cross-country perspective but the empirical evidence is fairly inconclusive[2].

Most of the empirical studies developed so far take a microeconomic perspective.[3] 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.

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 '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 expenditure and pollution abatement costs and find a positive correlation.

In a very 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*"[4].

This paper aims to provide a contribution in this respect investigating the channels through which tighter environmental regulation affects productivity and innovation. Our analysis is focused on a sample of European economies over the period 1995-2008.

2 See table 1 in the appendix.
3 See Koźluk and Zipperer, 2014.
4 Albrizio et al (2014).

We contribute to the existing literature evaluating the impact of environmental regulation on innovation and productivity adopting a cross-country macroeconomic perspective. We investigate the mechanisms through which different environmental stringency proxies affect innovativeness and productivity growth in the main EU member countries. 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 growth.

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

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

The European Union has been very sensitive and active in the design of environmental and climate regulation policies since the beginning of the seventies. The European Commission can be identified as a motivating power for environmental negotiations at the World level that strongly supported the achievement of two United Nations climate treaties: the UN Framework Convention on Climate Change (UNFCCC) in 1992 and the Kyoto Protocol in 1997.

Additionally, the introduction of the EU Emission Trading Scheme (Directive 2003/87/EC)[5] and the directives of the 2020 Climate and Energy Package on CO2

5 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.

emission reduction (2009/29/EC, 2009) and renewable energy (2009/28/EC, 2009) are two of the most significant EU policy interventions.

In 2005, the EU launched the European Union Emissions Trading System (EU ETS), the first large greenhouse gas emissions trading scheme in the world. The EU ETS is a relevant commitment to the strategic reorientation of environmental policies in the EU 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 (MBI). The purpose of MBI is to encourage firm's behavior by means of market signals rather than of 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.

The Emissions Trading System is a market based instrument to control pollution by providing economic incentives to reduce the emissions of pollutants. By means of emission trading the market attributes a price to environmental externalities that allows the actors to internalize the cost related to the environmental negative effects of their activities. However, a recent review of the effectiveness of environmental policy instruments showed mixed results about their potential to generate innovative spillovers (Kemp and Pontoglio; 2011)[6].

The characteristics of the environmental policy framework can affect the rate and direction of innovation of pollution abatement technologies. This evidence stimulated a number of empirical studies to evaluate the influence 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

6 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).

suggesting that market based instruments are more likely to induce innovation compared to direct forms of regulation[7].

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. This commitment is going to be implemented through a package of binding legislation. The EU has also offered to increase its emissions reduction to 30% by 2020, conditional to the commitment by other major emitting developed and developing countries to reduce their emissions under a future global climate agreement.

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

III. 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)[8]. In this paper we test the narrow hypothesis assuming that certain types of environmental regulation, those designed to target the outcome rather

7 For a survey see Jaffe et al., 2002; Popp et al., 2009.

8 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.

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 was relatively higher experienced faster productivity growth.

To analyze this assumption we adopt a difference in difference approach as in Rajan and Zingales (1998). They 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:

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

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 Narrow Version of the Porter Hypothesis NVPH holds) is supported by the data. That is well-designed environmental policies can positively affect productivity growth (e.g. there is a double dividend). Then, the TFP regression allows to check 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[9].

In a second step, 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) as 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.

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

If α_2 is positive and significant the relevance of NVPH is confirmed also by an indirect test.

As for environmental stringency indicators, it is relevant to notice that policy makers can choose between alternative policy instruments, and that their choice is strongly influenced by the degree of incentives to develop environmental friendly technologies. They can select mainly between the two categories mentioned above: market-based and command and control taking into account that MBI are more flexible since they provide incentives to the reduction or removal of negative environmental externalities while command and control instruments are more strict as they establish binding rules (i.e. emission standards, process/equipment specifications, limits on input/output/discharges) [10].

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),

9 See table 7 in the appendix for a description of the variables.

10 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)

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[11].

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

[Chart 1]

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)[12:] i) CO^2 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[14] and iv) a dummy for "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 particular, command and control measures have been criticized for restricting technological progress since they do not provide any incentive to innovate [15]. 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.

11 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.

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 On the whole, most European countries have fairly high levels of environmental taxation – at least compared to the other OECD countries.

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

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 NVPH hypothesis.

Finally, we tested equation 3 including some interaction terms to evaluate the differential impact 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 the environmental stringency measures are mainly related to emission reduction and for this reason they might have had a stronger 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 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[16.] 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 a Hausman specification test to check the presence of correlation between explanatory variables and individual effects.

Equation (1) can be affected by endogeneity and measurement errors so that we perform also instrumental variable regressions.

16 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.

IV. Estimation results: is there a double dividend?

Table (2) shows the estimation results for equation (1). We run fixed effects (columns 1 and 2) and instrumental variables regressions (columns 3 and 4). Coherently with the empirical production function literature[17], 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 driven by the market based component of the composite indicator (eps_mb). Policy stringency indicators are lagged since the productivity effects of policy changes might be lagged in time.

[Chart 2]

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, 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.

[Table 2]

Table 3, confirms previous results 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 3]

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

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 4).

The inclusion of an interaction term between the policy indicators and capital stocks provides additional insights to the analysis. With the inclusion of these terms, the estimated coefficients indicate a different effect of ICT on labour productivity growth after and before the introduction of the ETS.

The synergy between ETS and ICT is positive and statistically 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.

[Table 4]

The positive effect of EU environmental measures is robust also when we look at ICT capital accumulation (Table 5), 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 influence of environmental policies on R&D is somehow difficult to catch, at least at aggregate level.

[Table 5]

Finally we investigate the relationship between a measure of Total Factor Productivity growth and our environmental policy indicators.

[Table 6]

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 6). The introduction of the European trading system has a positive impact on TFP 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.

Conclusions

In this paper we explore the relationship between environmental policy stringency, productivity and innovativeness 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 environmental stringency measures on average did not erode competitiveness in the EU member economies but stimulated innovations and productivity.

Particularly, market based provisions, as an aggregate and with respect to specific provisions (i.e. ETS, environmental taxes), positively affected productivity growth. They determine a positive impact both directly and indirectly via ICT capital stocks, thus being effective in shaping the productivity and innovativeness within EU. More specifically the environmental taxes had a larger impact on labour productivity growth and ICT capital accumulation.

As for the command and control measures we found non significant results with the exception of the ratification of the Kyoto agreement that had a negative impact on ICT capital stock 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 ICT capital accumulation.

Our findings confirm the assumption that the gradual strategic reorientation of environmental policies in the EU have been more effective in stimulating productivity and innovation than setting explicit directives about pollution levels or control methods.

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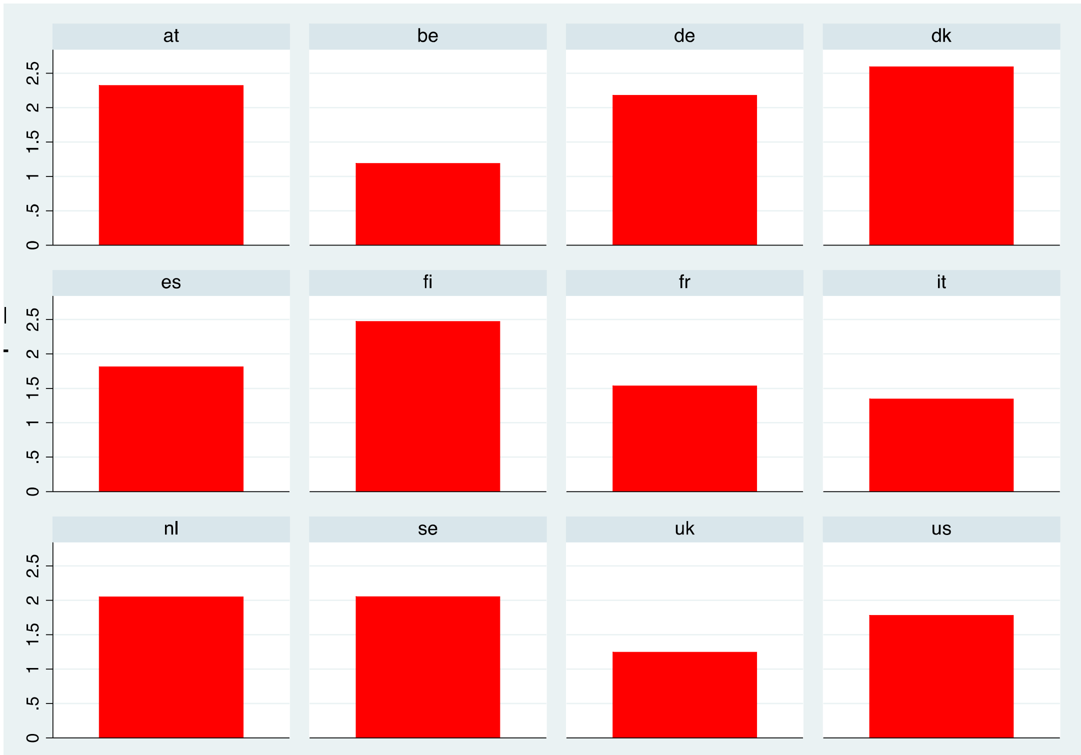
Appendix

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. 2010°	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.

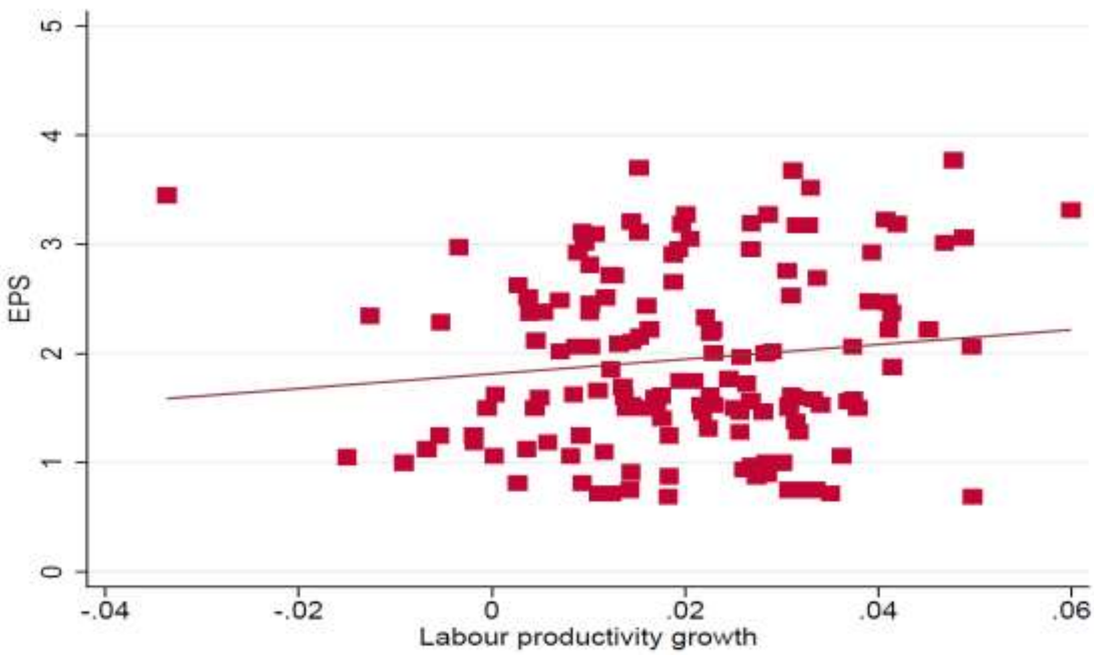
Source: Kozluk T and V. Zipperer, (2014).

Chart 1 Environmental Policy Stringency Indicator (EPS)



Source: Albrizio 2014

Chart 2 EPS vs labour productivity growth: 1995-2008



Tab 2 Labor 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

Tab 3 ICT, R&D and EPS

FE	(1) ICT	(2) 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

Table 4 – 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	0.659	0.414	0.622	0.436	0.635	0.413	0.640
Hausman test (c^2)	10.52 (0.31)		13.4 (0.00) 3		10.52 (0.31)		6.78 (0.56)		3.88 (0.87)	

Standard errors
*** p<0.01, ** p<

Table 5 ICT, R&D and “European” environmental provisions

FE	(1) ICT	(2) 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

Table 6 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

Table 7 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 8 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
Trade openness	Export +Import/2 in US dollars current prices	Source: OECD