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Via Voltapaletto, 11 – 44100 Ferrara

Quaderno n. 1/2010

January 2010

On the green side of trade competitiveness? Environmental policies and innovation in the EU

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Abstract

This paper aims at exploring how the competiveness of the EU economy, here captured by the export dynamics over a fairly the medium run (1996-2007), has been affected by environmental regulation both on the public and private sector side, The strong and weak versions of the Porter hypothesis are tested by specifying the export dynamics of four aggregated manufacturing sectors classified by their technological content, estimated with a dynamic panel data estimator applied to a gravity model of international trade.
When testing the strong version on export performances of manufacturing sectors, the overall effect of environmental policies is not in conflict with exports competiveness. In some cases we observe positive relationships, in other negligible, and when negative they seem to be circumscribed to the very short run. When testing the weak version using export flows of environmental goods, environmental policies, public R&D expenditures as well as patenting activities, all foster competitive advantages of green exports. Public policies and private innovation patterns can trigger higher efficiency and higher value embodied in products, or in other words environmental-friendly process and product innovations can turn a perceived production cost into a net benefit, thus giving some useful advice for policy makers involved into the new wave of environmental tax reforms actually debated at the European Union level.

Keywords: environmental policies, Porter hypothesis, technological innovation, export performances, gravity model, EU competitiveness.

J.E.L. codes: F14; F15; O14; Q42; Q48; Q55; Q56

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1. Introduction

The competiveness of economic systems is a key factor for both economic development and environmental sustainability achievements. This paper deals with the core competiveness performance in the EU, with a focus on exports performance, by conceptually and empirically bringing together different piece of the research puzzle: the negative, positive, or negligible economic performance effects of stringent environmental policy, the potential win-win effects that could derive from a Porter-like effect, the potential of innovation for improving both efficiency and product values in markets. Along such a reasoning, economic and environmental performances may go hand in hand, without conflicts generally prescribed by a neoclassic framework (Gray and Shabdegian, 1995). Hence, the analysis of efficacy through ex-post assessments should complement efficiency analysis by a dynamic assessment of economic instruments and innovation effects on the economic performances (Hahn and Stavins, 1994; Van den Bergh, 2007).

A more general framework under which this paper can be placed regards the linkages between trade openness, worldwide economic integration and related environmental effects (Managi et al., 2009). In particular, when the focus is on trade & environment related issues and the specific effects generated by environmental regulation on trade comparative advantages, two prevailing– often conflicting but not necessarily - perspectives are the pollution haven hypothesis (Letchumanan and Kodama, 2000; Grether et al., 2006; Grether, 2008; Peters and Hertwich, 2007; Levinson, 2010; Muradian *et al.*, 2002) and the Porter hypothesis (PH hereafter, since Porter and van der Linde, 1995; Jaffe et al., 1995; Portney, 2008). According to Copeland and Taylor (2004), environmental policy enters in a Heckscher-Ohlin theoretical framework as a (constraint to) factor endowment. Thus, the introduction of more stringent environmental regulations is potentially harmful for the productivity and competitiveness of the domestic firms facing higher productive costs. This could bring about delocalization of production driven by the relatively higher burden of environmental regulation in advanced countries. Diverse environmental and non environmental price and endowment based trade factors nevertheless drive trade. The possibility of a "green Leontief" paradox cannot be excluded: developing countries may gain from extra trade generated by different strength of the regulatory framework, with extra exports being less pollution intensive than extra imports, adding complexity to the pollution haven hypothesis (Dietzenbacher and Mukhopadhay, 2007). Most reasonings revolve around the assessment of 'environmental terms of trade' between regional areas or countries (Li and Hewitt, 2009; Straumann, 2003)

As regarding to the Porter hypothesis[2], up to the development of such framework, the general idea was that the fulfilment of environmental regulation would be likely to reduce the competitiveness of the involved sectors/firms. On the contrary, the so-called 'Porter hypothesis' suggested to test the potential complementarities and (private) beneficial effects of properly designed environmental regulations, which are likely to emerge in dynamic settings with innovation and environmental impure public goods as key issues (Mazzanti and Zoboli, 2009).

[2] Recently, a significant body of literature has emphasised the shortcomings of the standard normative economic theory of environmental policy (Baumol and Oates, 1988) in explaining the patterns of environmental innovation and, above all, in guiding policy-makers in the setting of an optimal policy mix. Rammel and van der Bergh (2003) have emphasised that traditional economic approaches are inappropriate for dealing with the dynamics of structural and adaptive changes (Kemp, 1997; van der Bergh and Gowdy, 2000; van der Bergh, 2003; van der Bergh *et al.*, 2007; Nill and Kemp, 2009).

Export dynamics and technology diffusion here play a strong role. While it may be true that some growth patterns are unsustainable from a national point of view, when the decoupling process of emissions from growth could be an over optimistic outcome along a consumption based perspective (Musolesi *et al.*, 2009; Mazzanti and Musolesi, 2009; Watson and Moll, 2008), trade patterns and international relationships may lead to reciprocal benefits if negative externalities are dealt with and property rights regimes are properly defined (Chichilnisky, 1994). To some extent, the combination of environmental policies with private (and public) innovation strategies may lead to increasing environmental efficiency in both exports and imports (Levinson, 2009, 2010), thus creating the conditions for a race to the top instead that to the bottom along the development and globalization processes (Costantini and Monni, 2008)[3]. Interestingly, according to Lovely and Popp (2008), environmental regulations follow standard diffusion curves, so that late adopters can learn from early movers, and international trade drives faster adoption. The EU has the possibility to play a leading role engaging a race to the top in putting environmental standards at the top of the policy agenda[4].

The capacity of environmental policies to reinforce international competitiveness, as claimed by the recent revision of the Lisbon Agenda for the EU, is even more relevant when the reasoning on the causes of the current crisis and how to move towards new growth scenarios as fast as possible, assigns a key role to environmental sustainability. The years 2009-2011 witness the implementation of generally strong and somewhat 'green' recovery packages (Bowen *et al.*, 2009; HSBC, 2009; Edenhofer and Stern, 2009). Green recovery measures should deal with two problems - the economic and climate crises - simultaneously[5]. The greening of exports may specificall bring to structural competitive advantages, but it needs to be supported by coevolving innovation and environmental policy instruments in the transition towards sustainable pathways (Geels, 2004; Geels and Schot, 2007).

According to Parry (2009) for the US and to Anderson and Ekins (2009) and PetrE (2009) for the EU, the implementation of carbon taxes and/or auctioned permits is a fruitful way to reconcile in this recession environmental and economic performances, where ETR can be shaped on a real 'policy based' target perspective, including competiveness aims. As debated in the rich discussion on Environmental Tax Reforms (ETR) in the 90's, double and triple dividends *could* emerge (Bosquet, 2000; Majocchi, 1998). In the light of this revitalized debate we are interested in specifically understanding how environmental regulation and technological innovation have influenced / may influence the economic competiveness of the EU.

We specifically aim at exploring how the competiveness of the EU economy has been affected by the intensity of energy and environmental taxation, by public and private efforts in R&D, and by innovation activities such as

[3] Higher pollution and materials embodied in imports could go along with positive green export performances as international specialization change and economic development and policies may change comparative advantages. We nevertheless believe that a positive correlation between environmental policy and innovation, and competitiveness, in a leading region such as the EU, can generate a diffusion of environmental standards, technologies and general performances, stimulating the mentioned race to the top, both through trade and also FDI flows (Albornoz et al., 2009; Perkins and Neumayer, 2008).

[4] The Environmental Technology Action Plan pursues European leadership in energy and environmental technologies/products; world market for environmental products is around 500 billion. Environmental goods/technologies market in EU25 is worth 227 billion € (2,2% GDP), Direct and indirect employment: 3,4 million, EU might achieve 30% of world market (50% for water and waste technologies).

[5] The overall impression is that direct intentional action on green growth and climate change, as well as R&D, have still a limited role in the national recovery plans of EU countries (Saha and Von Weizsacker, 2009).

patenting. The effects of such core drivers on competitiveness are controlled by numerous structural, institutional, and trade specific factors relying on a well developed theoretical framework as the gravity equation approach. On such a framework we thus test both the strong version of the Porter hypothesis – as regulations and policy, and induced innovation enhance economic performances, at least in the medium run, for *the economy as a whole*, and the weak version of the Porter-like effect, as policy and innovation positively impact only on the 'green side' of the economy. In this latter case we focus on the export flows performances of the complete list of environmental goods under negotiation within the WTO[6].

As far as the EU is concerned, the focus on export dynamics as a source of general economic competitiveness is even more relevant for at least two reasons. First, even if the EU needs a more balanced growth sustained also by private consumption and investments, it is with China one of the largest exporting regions.

The second reason is that the EU is a leader in the design and adoption of stringent environmental policies (climate change, the 20-02-20 strategy), and many fears have arisen about the potential negative effects of such unilateral production constraints for EU firms. A 'sustainable' robust export led economic performance is a way towards to sustainable high-skilled job creation, also a step for moving away from the low productivity trap most EU countries have experienced and may experience in the post crisis.

The rest of the paper is structured as follows. Section 2 discusses the relevant framework and the main research hypotheses tested. Section 3 presents conceptual and methodological issues and the framework of the gravity empirical model. Section 4 comments on main outcomes of dynamic panel regressions. Section 5 concludes.

2. Competitiveness, innovation and environmental policy

2.1 The development of the debate from the PH

Many empirical studies have analysed the effects that environmental polices produce on innovation and competitiveness either by the investigation of the effects of environmental regulation on international competitiveness and, indirectly, on a possible induced technical change or specifically analysing the direct impacts on the innovation performances (Kemp, 2000).

More stringent environmental regulations have been seen as potentially harmful to the productivity and competitiveness of the domestic industry since they lead to higher costs faced by firms (Brock and Taylor, 2004; Copeland and Taylor, 2003, 2004; Antweiler et al., 2001; Bommer, 1999). However, building on seminal contributions by Schumpeter on the *creative response* of economies in adapting to changes in external environment and on the increasing literature on the inducement effect produced by environmental regulation, a growing consensus is arising around the PH: not to be taken for granted but a possible empirical outcome to be verified case by case. Corporate social responsibility (CSR) behaviour (Portney, 2008; Rehinardt et al., 2008) and race to the top innovation dynamics can be present in economic/institutional frameworks characterised by regulated markets, wherein more innovative firms take a long run 'beyond compliance' perspective to profit making and

[6] To the best of our knowledge, there are no attempts that give robust empirical evidence to strong Porter effect, while previous contributions on the weak version of the PH focused on only specific environmental sectors.

thus investments strategy. Innovative firms and more innovative sectors go beyond the edge of technological/policy frontiers, changing and enhancing structural competitive advantages. Institutional, economic, trade and policy issues contribute to the creation and necessary diffusion of leading innovations (Rennings and Smidt, 2009; Popp, 2010). The empirical studies on the PH have not been successful till now in finding robust support for the strong argument, while they have mostly been successful in the weak argument when evidence is based on specific industries rather than broad sectors or economic systems (Albrecht, 1998; Murty and Kumar, 2003; Wagner, 2003, 2006). Analogously, the main contributions addressing the impact of environmental regulation on technological innovation using patent data (e.g., Jaffe and Palmer 1997; Lanjouw and Mody, 1996; Popp, 2003) have not found unanimously robust evidence. Nevertheless, more recently, there has been increasing empirical evidence to support the argument that stringent environmental policies lead to technological innovation in general (Hascic *et al.*, 2008), and specifically in the (renewable) energy sector (Johnstone *et al.*, 2010; Walz *et al.*, 2008).

There is also an increasing consensus about the potential win-win effects deriving from well combined environmental and innovation strategies, both on the private and public side (Jaffe *et al.*, 1995, 2003, 2005; Kemp, 1997, 2000). The introduction of a new environmental regulation may well represent a stimulus for new research only if innovation systems are equipped with adequate scientific and technological knowledge so that their responses are coherent with the environmental goals (Costantini and Crespi, 2008, 2010; Rennings, 2000). In this respect the use of an *appropriate mix* of technology policies and environmental policies emerges as a crucial factor in directing economic systems towards sustainable and competitive paths of economic growth (van der Berg and Kemp, 2006).

Integrated studies on the analysis of innovation dynamics, the efficacy and efficiency of policies, and the effects of environmental policies and environmental innovation/strategies on socio-economic performance, have enriched with micro-economic details the implications arising from macro models (Mazzanti and Montini, 2010). Nevertheless, economic effects have received less attention from the empirical literature. Building upon the literature on the links between innovation and economic performance (Rennings et al., 2004; Cainelli *et al.*, 2006; Cainelli et al., 2010a,b), recent works have looked at the effects of environmental (induced) innovation on economic performance.

Within it, the analyses of export dynamics for technology-distinguished sectors including green manufacturing goods is a relatively new research field. Such economic performance are actually extensively analysed by use of macro econometric 'general equilibrium' models of Keynesian flavour. Very recently, on the edge of the new emphasis on ETR and climate change, various estimates on future scenarios deriving from the implementation of (green) recovery packages and environmental policies were provided (Pollitt and Junankar, 2009a,b). In particular, Barker et al (2007, 2009) and Pollitt and Chewpreecha (2009) provide evidence on productivity, competiveness and carbon leakage effects of ETR using a highly disaggregated EU macro econometric model.

An overall conclusion that emerges and can inform current policy making is that the mild (between 0.2-1% of GDP) ETR implementations did not produce and are not expected to produce negative effects on employment, GDP, and of some interest to us, on competitiveness (export performance). The only relatively possible negative outcome is a reduction of productivity, depending on the fact that the circumscribed effect of ETR increases employment more than GDP. As far as the scenario deriving from the hypothesis of reaching the threefold 20% 2020 targets through a revenue neutral EU27 carbon tax, estimates show that the productivity effects are highly heterogeneous across countries, but exports and imports are unaffected, especially under the hypothesis that tax revenues are recycled by fostering investments in efficient machinery[7].

2.2 Principal Hypotheses

Complementarily to macro econometric works, NAMEA based (Mazzanti et al., 2008) and industry based analyses in environmental economics and policy (Cole et al., 2005; Cole and Elliott, 2007), we explore the sector export dynamics of the EU_{15}. Our first two main research hypotheses regards the effects on competitive advantages deriving from energy taxes (HP 1a), and specific environmental taxes (HP 1b). We test also whether such effects on exports are technology/sector specific. Pollution abatement control expenditures (PACE) are included for comparison with the relevant literature (HP1c). Tables A3-4 in the appendix summarise descriptive statistics, sources and hypotheses. We do expect positive or negligible effects in the medium run, and possibly negative effects in the short run – simultaneous or limited temporal lags - according to the Porter idea of regulatory driven competitive advantage in the medium run.[8]

Long run leadership must be reliant on innovation drivers. Eco-innovation is becoming the conceptual reference point for many regional and international public policies and management strategies (Rennings, 2000; Kemp and Pearson, 2007). Eco-innovation, being formalized or not, recently became a point of attraction of research in environmental economics. Innovation indicators for the environment suffers from the usual limits of innovation indicators, the often organizational nature of eco-innovation, the limited possibility to distinguish environmental from other innovations in many cases (Arundel and Kemp, 2009; Arundel et al. 2003, Kleinknecht et al. 2002, Kemp and Oltra, 2007). These features explain a general accepted pluralism in the use of indicators (Horbach and Rennings 2007); patenting is one major way of capturing (the various rents/benefits of) environmental innovation (Carrion-Flores and Innes, 2010; Dechezleprêtre et al., 2009).[9] Existing analyses in the literature mainly focus on innovation drivers or effects of patents on environmental performances (through policy induced innovation effects).[10] We here exploit different indicators, also setting various temporal lags. We define as driver of exports dynamics a sector specific innovation output indicator based on a stock of knowledge concept relying on patents (HP 2), as well as a technology input dimension, as we test the role of overall R&D expenditures (HP 3a) and specific environmental *public* R&D expenditures (HP 3b). A technological capabilities index is also included to capture (HP4) overall innovative contents. All variables will be discussed in the next section; table A4 shows a summary of variable related issues.

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[7] At sector level, another fruitful direction for research has actually been in recent years the analysis of NAMEA data. Though some have recently included trade openness, 'policy' analysis, and R&D as additional merged factors to NAMEA (Marin and Mazzanti, 2009), the core value of NAMEA remains the analysis of the sector based income-environment relationship.

[8] This reasoning theoretically also embeds this political economy issue in the above mentioned realm of 'dynamic efficiency' of environmental policies (Hahn and Stavins, 1994, Kemp, 1997, Del Rio, 2008).

[9] Major limitations in using patents arise from the lack of a specific class of 'environmental patents' in the international classification system (IPC). Therefore, eco-patents have been then often used to address specific technologies, for example renewable energies or air pollution technologies (Popp 2005, de Vries e Withagen, 2005).

[10] Jaffe and Palmer (1997), Brunnermeier and Cohen (2003), Popp (2002, 2006a,b), Johnstone et al. (2010).

Alternatively or complementary to input and output technological innovations organisational innovations, such as Environmental Management System (EMS) and ISO14000, may provide further pillars to competitive advantages (Arimura et al., 2008; Barla, 2006 Johnstone and Labonne, 2009). In effect, Ziegler and Nogareda (2009) study the co-causation links between organisational and technological innovation (Rennings et al., 2006). The two innovations realms can thus be interrelated and provide correlated or additive effects to innovation and economic performances. Wagner (2007) has analysed EMS and ISO correlation in adoption, and their effects on environmental performances. We verify whether organisational innovation is playing a role as a driver of competiveness (HP 5).

3. Econometric issues, the model and the dataset

3.1 Recent advancements in gravity models

For the purpose of our analysis, we choose a gravity equation framework drawn from the international economics literature since it constitutes a theoretically and statistically robust basis for analysing the impact of public policies and innovation on export dynamics.

Recent contributions on gravity model for trade flows have arisen three major issues: the role of multilateral resistance terms (MRTs), the statistical bias produced by zero trade flows, and the high persistency of bilateral trade in a time series context.

Regarding the first issue, according to Anderson and van Wincoop (2003) multilateral trade resistance terms (MRTs) should be added into the empirical estimation to correctly estimate a theoretically-based gravity model by including country dummy variables. The empirical contributions by Baldwin and Taglioni (2006) and Baier and Bergstrand (2007) suggest that, by including specific country-pairs' time-variant fixed effects, the MRTs can be represented in an appropriate way also for a panel dataset. As we are considering a panel version the log-linear form is

$$\begin{aligned} \ln X_{ijt} = {} & \alpha_{ij} + mrt_{ijt} + \gamma D_{ij} + \beta_1 \ln Y_{it} + \beta_2 \ln Y_{jt} + \beta_3 \ln P_{it} + \beta_4 \ln P_{jt} + \\ & + \beta_5 \ln G_{ij} + \beta_6 \ln Z_{ijt} + \beta_7 \ln F_{it} + \beta_8 \ln F_{jt} + \upsilon_{ijt} \end{aligned} \quad (1)$$

where mrt_{ijt} represents time-varying multilateral resistance terms for each pair of countries.

The second issue concerns the problem related to the existence of a large number of zero trade flow values, which may produce significant biases in the statistical procedure. Recent contributions have proposed two main alternative solutions. The first suggests the adoption of a non-linear estimator, such as the Poisson-Pseudo Maximum Likelihood estimator (Santos-Silva and Tenreyro, 2006. The second is a Heckman's two-stage procedure. The estimation is used to calculate the inverse Mills ratio, which is then included (sample selection bias) in the second-stage gravity model. Moreover, according to Helpman, Melitz and Rubinstein (2008) (hereafter HMR), a large part of statistical bias produced by zero is not due to a sample selection problem but to neglecting the impact of heterogeneity. In particular, the two-steps procedure may give poor results if the first and second stage equations are estimated by using exactly the same explanatory variables (Wooldridge, 2002).

Some covariates related to the costs of establishing trade flows should be included only in the first-stage, accounting for both self-selection of firms into export markets and their impact on trade volumes.[11]

The third issue concerns a dynamic specification of trade flows that allows addressing the serial correlation caused by a strong time persistency in trade flows related to the presence of sunk costs (Bun and Klaassen, 2002; De Benedictis *et al.*, 2005). To this purpose, System GMM proposed by Blundell and Bond (1998) is a proper estimator, making it possible to correct for autocorrelation of residuals, while retaining all fixed effects and time invariant variables, contrary to a simple GMM estimator. Bond and Windmeijer (2002) show that it is more efficient than the Arellano and Bond GMM if the panel is short in time (*T*) and large in cross-section units (*N*) and if it includes persistent time series.

3.2 The model and the dataset

In our panel dataset, trade flows include many zero values, and at the same time trade series appear to be quite persistent over time. Moreover, it is large in cross-section units and short in time, and trade flows show strong persistence in the short-run. The best way to cope with these problems is to adopt the two stages HMR procedure, with a panel probit estimator for the first stage and a System GMM for the second dynamic equation.[12]

From the first-stage equation we have calculated two variables explaining the role played by the extensive margins ($fhet_{ijt}$) and the intensive margins ($mills_{ijt}$) of trade as expressed in equation (2)

$$\begin{aligned} x_{ijt}^{k} &= \alpha_i + \delta_j + \tau_{ijt} + \sum_{p=1}^{n} \lambda_p x_{ij,t-p}^{k} + \beta_1 BORDER_{ij} + \beta_2 dist_{ij} + \beta_3 land_j + \\ &+ \beta_4 LOCK_j + \beta_5 mass_{ijt} + \beta_6 sim_{ijt} + \beta_7 endw_{ijt} + \beta_8 fhet_{ijt}^{k} + \\ &+ \beta_9 mills_{ijt}^{k} + \beta_{10} inn_{i,t-q}^{k} + \beta_{11} inn_{j,t-q} + \beta_{12} envreg_{i,t-q} + \beta_{13} D + \varepsilon_{ijt} \end{aligned} \qquad (2)$$

where lower case letters denote variables expressed in natural logarithms and upper case letters indicate dummy variables.

The country sample here considered is made up of 14 *i-th* exporting countries (all EU15 members where Belgium and Luxembourg are together) and 145 *j-th* importing countries,.[13] The time period is 1996 – 2007: the full sample therefore covers a total of 24,360 observations.

The vector of dependent variables is alternatively expressed by bilateral export flows from country *i* to country *j* at time *t* in current US$ for five *k-th* sectors representing four distinct macro-sectors and one 'green sector'. For the purpose of estimating the strong PH, we consider four aggregated sectors classified by OECD (2008) as high, medium-high, medium-low, and low technology industries by using the ISIC Rev.3 classification (as

[11] In addiction a second variable related to the impact of firms' heterogeneity (the extensive margins) is constructed as the predicted probability of trade from country i to country j.

[12] According to Antimiani and Costantini (2009), the standard HMR two-stage procedure should be adapted in a panel setting, by including a time-variant control variable for firms' heterogeneity in the first-stage probit selection equation.

[13] The 145 *j-th* partners have been chosen on the basis of data availability, and considering that in all cases export flows from *i-th* countries to the sum of *j-th* constitute more than 95% share of total *i-th* country exports.

described in Table A1 in the Appendix). The weak PH is tested on the fifth sector here defined as an aggregation of all HS1996 codes listed in Steenblick (2005a, 2005b) as environmental goods which are actually under a specific negotiation in the WTO.[14]

The standard 'gravity variables' are the followings. $BORDER_{ij}$ is a dummy variable for the existence or non-existence of a common geographical border between each country pair. The log of distance ($dist_{ij}$) is calculated as the great-circle formula (Mayer and Zignago, 2006), and $land_j$ represents the log of surface area of importing countries. We expect that coefficient for $BORDER_{ij}$ should be positive, while those for $dist_{ij}$ and $land_j$ should be negative.[15] Landlocked *j-th* countries are also represented by a dummy variable (*LOCKj*), as well as the existence of a common language between country pairs, used in the first stage probit equation. We refer to tables A2-4 for correlations, descriptive and other variables features.

Some standard combinations of variables explaining the role of the economic size of the trading partners are adopted. We included a measure of relative country size by computing the similarity index of the GDPs of two trading partners (sim_{ijt}) calculated as (Egger, 2000):

$$sim_{ijt} = \ln\left[1 - \left|\left(\frac{GDP_{it}}{GDP_{it} + GDP_{jt}}\right)^2 - \left(\frac{GDP_{jt}}{GDP_{it} + GDP_{jt}}\right)^2\right|\right] \quad (3)$$

The larger this measure, the more similar the two countries are in terms of GDP, and the greater the share of intra-industry trade. A synthetic measure of the impact of country-pair size as a proxy of the "mass" in gravity models, $mass_{ijt}$, is:

$$mass_{ijt} = \ln\left(GDP_{it} + GDP_{jt}\right) \quad (4)$$

A measure of the distance between relative endowment of domestic assets, $endw_{ijt}$, is approximated by eq. (6) where GDP per capita is a proxy of the capital-labour ratio of each country:

$$endw_{ijt} = \left|\ln\left(\frac{GDP_{it}}{POP_{it}}\right) - \ln\left(\frac{GDP_{jt}}{POP_{jt}}\right)\right| \quad (5)$$

The larger this difference, the higher is the volume of inter-industry trade, and the lower the share of intra-industry trade.

We have included sector-specific variables for representing the role of innovative capacity in explaining trade performance for each sector. It is worth noticing that this disaggregation is possible only for the four sector related to the strong PH, while a commonly accepted definition of an environmental patents class is still far from

[14] For a broad representation of trends in revealed comparative advantages (RCA) for export flows of the five k-th sectors see Figure A1 in the Appendix.

[15] While distances are considered as a proxy of transport costs, the surface area of importing countries gives a dimension to the role of intra-national trade, and the larger the country, the higher its intra-national trade share with respect to total trade.

being accepted (OECD, 2008b).

The explanatory variable associated with the role of technological innovation for exporting countries $inn_{i,t-q}^{k}$ has been built as an adaptation of the stock of knowledge function based on patent count. The stock of knowledge is defined following the accumulation function (Popp, 2002), with the exclusion of the diffusion component.[16] Our data allow assigning patents as 4-digit codes of the International Patents Classification (IPC) for inventing industries so that our stock of knowledge function is:

$$INN_{it}^{k} = \sum_{s=0}^{t} PAT_{is}^{k} e^{[-\beta_1 (t-s)]} \qquad (6)$$

where INN_{it}^{k} is the knowledge stock in industry *k* for each *i-th* exporting country at time *t*. Here PAT_{is}^{k} represents the number of patents produced by industry *k* in country *i* in year *s*, and *s* represents an index of years up to and including year *t*. β_1 is the decay rate, with an average value of 0.3 (as a standard value from the literature). The final variable $inn_{i,t-q}^{k}$ is calculated as the logarithm of the stock for each year; the lag structure is endogenously determined.

The stocks allow estimating an overall knowledge production function, considering that in most cases the capacity to apply for a patent (international offices such as the European Patents Office, EPO) largely depends on previous experience, so that the higher the number of patents granted to a certain firm, the greater the probability that this specific firm will apply for new patents.[17] There is convincing empirical evidence that cumulative domestic innovation efforts are an important determinant of productivity and competitiveness (Coe and Helpman, 1995; Eaton and Kortum, 2002).

The classification of patents data is taken from Schmoch *et al.* (2003) and Verspagen *et al.* (2004),[18] referring to 46 industrial sectors, classified by using ISIC Rev.3, which are related to the International Patents Classification codes issued by the World Intellectual Property Rights Organization (WIPO). We have condensed the original 46 sectors into the 4 macro-sectors used for the Annual OECD Technology Scoreboard Report, thus obtaining a set of industrial sectors where data on trade flows, structural characteristics and patents are fully comparable.[19]

In order to catch the propensity of *j-th* countries to import goods with different technological characteristics (Filippini and Molini, 2003), we computed a technological capabilities index (Archibugi and Coco, 2004) with

[16] This choice is related to the fact that Popp (2002) accounts for the diffusion of technologies by assigning patents to the end-user sectors, rather than to the innovation producer alone. In our case, we are interested in investigating the knowledge production process.

[17] We have considered only EPO applications, because as we consider only patents applied to the European Patents Office, which is generally more expensive than patenting in domestic patents offices, we assume that the marginal benefits from patenting are at least equal to marginal cost, so that firms apply to EPO only for economically valuable inventions.

[18] There are many contributions on concordance techniques for the assignment of patent data by field of technology to a classification by economic sector, mapping patent product or process categories into the economic sectors responsible for their creation and subsequent use (Kaplinsky and Santos-Paulino, 2006).

[19] For a broad representation of trends in (green) technological revealed comparative advantages for the accumulation of knowledge stock into the four macro-sectors see Figures A2-3 in the Appendix.

their ARCO index.[20] The final formulation of our inn_{jt} index for each country *j* at time *t* represents the diffusion of technological infrastructures and the creation of human capital and is:[21]

$$inn_{jt} = \frac{1}{2}\left[\frac{1}{3}\left(\frac{\ln(Tel_{jt})}{\ln(Tel_{\max t})} + \frac{\ln(Internet_{jt})}{\ln(Internet_{\max t})} + \frac{\ln(Electr_{jt})}{\ln(Electr_{\max t})}\right) + + \frac{1}{2}\left(\frac{\ln(Edu_{jt})}{\ln(Edu_{\max t})} + \frac{\ln(Fdi_{jt})}{\ln(Fdi_{\max t})}\right)\right] \quad (7)$$

The final group of covariates ($envreg_{i,t-q}$) refers to several measures of environmental instruments adopted by the *i-th* exporting countries: energy and environmental taxation, innovation lever as public R&D (table A2) . Finally, in order to investigate whether some structural breaks occurred during the time span we have tested several year dummies: EU enlargement process, Euro currency adoption, European Emission Trading Scheme[22].

4. Empirical evidence

4.1 The drivers of export performances: the strong PH

4.1.1 Structural results

As far as the potential impact of a general regulatory framework may be highly differentiated among manufacturing sectors whose technological content is not homogeneous, while considering that a Porter-like effect mainly depends on induced innovation, our four macro-sectors disaggregation is clearly helpful to disentangle the pure innovation effect related to the specific sector characteristics from an inducement effect produced by environmental regulation stringency.

The use of a dynamic panel estimator is strongly required as the coefficients for lagged values of exports are always statistically significant. The optimal lag structure has been selected on the basis of the autocorrelation tests over the residual terms, when the *p*-value of the AR(2) test (two lags) does not fail to reject the null hypothesis of absence of serial correlation. The Hansen test on over-identification of instruments necessary to control for endogeneity - in our case typically the *i-th* country innovation and regulation variables as found previously in Jug and Mirza (2005) and Mantovani and Vancauteren (2008) – reinforces such a structure, apart from the low-tech sector.

Also for the *medium-low-tech* sector, the size and significance of (lagged) patent indicators is confirmed, highlighting minor problems of collinearity between policy and innovation variables.

[20] In order to represent the diffusion of technological infrastructures, we have accounted for Internet and telephone penetration (number of Internet, fixed and mobile telephone lines per 1,000 persons) and per capita electricity consumption. The second dimension, related to the creation of human capital, is the arithmetic mean of domestic efforts in accumulating human capital, expressed as the secondary gross enrolment ratio, and the influence produced by Foreign Direct Investments (FDI) inflows.

[21] We have tested several lag structure, but contrary to the case of the innovation stock of *i-th* countries, they have been checked exogenously.

[22] The variable for the enlargement assumes value 0 up to the moment when the new member state entered the EU, and value 1 thereafter. The structural break is 2002.

Table 1 – Estimations for the strong PH

	High Tech		Medium-High Tech		Medium-Low Tech		Low Tech	
$Export_{ij(t-1)}$	0.33***	0.33***	0.33***	0.31***	0.32***	0.34***	0.35***	0.36***
	(8.57)	(8.48)	(10.01)	(8.09)	(7.80)	(7.83)	(6.25)	(6.31)
$Export_{ij(t-2)}$	0.09***	0.08***	0.15***	0.15***	0.15***	0.17***	0.18***	0.18***
	(2.79)	(2.66)	(4.58)	(4.94)	(4.62)	(5.17)	(3.56)	(3.39)
$Distance_{ij}$	0.46	-2.28	-1.20	-2.73*	0.20	2.24	-0.43	-1.18
	(0.20)	(-0.68)	(-0.95)	(-1.72)	(0.12)	(1.07)	(-0.29)	(-0.81)
$Border_{ij}$	-4.96**	-6.86	-6.34***	-6.50***	1.20	-0.20	-4.19	-8.23
	(-2.18)	(-0.44)	(-3.10)	(-3.16)	(0.11)	(-0.02)	(-1.32)	(-0.76)
Land $Area_j$	0.53	-0.17	0.70	0.62	-0.08	-0.22	-0.17	0.08
	(0.60)	(-0.15)	(1.11)	(0.95)	(-0.17)	(-0.33)	(-0.18)	(0.10)
$Landlock_j$	-3.78	-8.34	-1.47	-1.96	1.53	0.06	1.14	1.23
	(-0.78)	(-1.29)	(-0.22)	(-0.34)	(0.60)	(0.02)	(0.32)	(0.28)
$Mass_{ijt}$	1.13***	1.03**	2.34***	2.53***	2.15***	1.39***	1.22**	1.11**
	(3.08)	(2.37)	(4.50)	(4.85)	(4.05)	(3.06)	(2.07)	(2.04)
$Similarity_{ijt}$	1.94***	1.83***	2.20***	1.82***	2.50***	1.98***	1.49***	1.50***
	(6.94)	(5.98)	(6.05)	(4.59)	(4.74)	(4.58)	(2.75)	(3.04)
Rel. $Endow_{ijt}$	0.23**	0.26**	-0.13*	-0.15	0.24*	0.16	0.05	0.01
	(2.03)	(1.94)	(-1.65)	(-1.56)	(1.92)	(1.58)	(0.51)	(0.13)
Firms Het. $_{ijt}$	1.87***	1.39**	0.84	0.66	1.55*	1.31	0.66	-0.19
	(3.14)	(2.01)	(0.77)	(0.49)	(1.78)	(1.46)	(0.31)	(-0.12)
$Mills_{ijt}$	-0.04*	-0.04*	0.04*	0.04*	-0.09**	-0.07**	-0.01	0.00
	(-1.84)	(-1.82)	(1.72)	(1.66)	(-1.99)	(-1.95)	(-0.23)	(0.10)
$Knowl_{iPATt}$	1.03***	1.01***	1.65***	1.77***	1.06***	1.05***	0.77***	0.56***
	(7.23)	(6.59)	(8.96)	(8.52)	(7.55)	(8.21)	(6.19)	(4.82)
$Knowl_{iPAT(t-1)}$	0.86***	0.83***	0.28	0.26	0.12	0.34**	0.39***	0.42***
	(5.09)	(4.65)	(1.53)	(1.46)	(0.74)	(2.31)	(2.98)	(3.67)
$Knowl_{jt}$	0.01	0.02	0.01	0.04	0.09*	0.06	-0.05	-0.04
	(0.33)	(0.38)	(0.40)	(1.26)	(1.69)	(1.31)	(-1.55)	(-1.20)
Ene-$Tax_{i(t-1)}$	-0.94***		0.23		1.10***		0.19	
	(-3.46)		(0.89)		(3.26)		(0.71)	
Ene-$Tax_{i(t-2)}$	0.76***		-0.42*		-0.12		-0.19	
	(3.17)		-(1.73)		(-0.40)		(-0.66)	
Env-$Tax_{i(t-1)}$		0.04		-0.17		0.18		0.06
		(0.28)		(-1.06)		(1.21)		(0.40)
Env-$Tax_{i(t-2)}$		0.71***		-0.18		0.30*		0.41**
		(3.29)		(-1.06)		(1.73)		(2.29)
Enlargement	-0.01	-0.01	0.25***	0.26***	0.04	0.01	0.03	0.03
	(-0.13)	(-0.06)	(4.77)	(2.91)	(0.77)	(0.23)	(0.71)	(0.57)
Euro	-0.19***	-0.21***	-0.03	-0.02	0.10*	0.15***	0.07	0.20
	(-5.23)	(-5.31)	(-0.83)	(-0.35)	(1.77)	(3.25)	(1.18)	(3.64)
Ets	-0.03	-0.03	0.04	0.07*	0.04	-0.03	0.00	-0.03
	(-0.95)	(-0.73)	(1.08)	(1.82)	(0.94)	(-0.61)	(0.06)	(-0.51)
Oecd	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No Obs.	15,236	15,236	15,377	15,377	15,209	15,209	14,519	14,519
Wald test	6,259	6,244	8,659	7,540	4,930	5,099	4,053	3,939
AR (1)	-9.31 (0.00)	-9.16 (0.00)	-8.60 (0.00)	-8.43 (0.00)	-9.52 (0.00)	-9.53 (0.00)	-6.18 (0.00)	-6.37 (0.00)
AR (2)	-1.09 (0.27)	-0.99 (0.32)	-1.14 (0.25)	-1.47 (0.14)	-2.02 (0.04)	-2.41 (0.02)	-0.71 (0.48)	-0.61 (0.54)
Hansen test	28.28 (0.40)	24.74 (0.59)	23.73 (0.31)	23.34 (0.33)	19.57 (0.55)	17.32 (0.69)	175.70 (0.00)	131.51 (0.00)

*Notes: Twostep robust specification has been used. Robust t-statistics in absolute value are reported in parenthesis. *, **, *** significant p-value at the 10%, 5%, 1%, respectively. AR(1) and AR(2) are tests – with distribution N(0, 1) – on the serial correlation of residuals. Hansen Chi-sq test for overidentification of restrictions (number of instruments).*

The geographical dimensions are not so relevant for explaining trade flows dynamics, except for the border effect, which is negative and statistically robust for high and medium-high tech sectors. It is quite intuitive that the propensity to export manufacturing goods with relatively higher technological content is reduced when the two trading partners share a common border. The common borders coincide with the EU market, whose effect is specifically controlled by the enlargement dummy (*Enl*) which is in turn positive and statistically robust.[23]

Within the vector of control variables valid for all *k* sectors that characterise a gravity model, many factors are significant and consistent with expectations. *Mass* and *Similarity* variables are the key drivers explaining trade dynamics at the general level. Recalling that *Mass* represents the role of global bilateral demand, the higher the value the greater the influence of demand factors in export dynamics. The positive coefficients for *Similarity* should be interpreted as a sign of the existence of intra-industry trade, which is more likely to occur in the higher sectors in the technology ladder, typically occurring between countries with similar endowment factors (Grubel and Lloyd, 1975).

The fitness of a two stages procedure finds validation from statistical robustness of both *Firms Heterogeneity* and selection bias (*Mills ratio*). It is also interesting to see that heterogeneous firm behaviours in trade patterns well explain export dynamics especially for the high-tech sector, quite consistently with higher trade sunk costs in respect with sectors with a lower technological content where the role of intensive margins of trade (or the selection bias) prevails. Finally, the strong Euro seems to have decreased competiveness only for the high tech sector and this may result from the relatively greater weight exercised by exchange rate valuation over export prices of high value added manufacturing goods.

4.1.2 Environmental policies

As regarding to the *high-tech sector*, it is the only one where we do find significant and persistent impacts on exports dynamics related to both energy and environmental tax levers. More specifically, the one-year lag for energy taxation shows a negative and significant (also in its size) coefficient, while the second lag turns out to be positive. Though we are on a short medium run reasoning, the alternate effects are consistent with the idea that in the very short run environmental tax (energy taxes in this specific case) exert more costs than benefits on economic performances, while when time goes by net effects may turn into positive ones. This result is perfectly consistent with earlier results by Popp (2002) on the inducement effect on innovation patterns played by energy prices, which foster the invention and diffusion of energy-saving technologies over the medium run.

In considering pure environmental taxation, net of energy revenues, the two lags structure is maintained: the first lag now is not hampering export dynamics, while the coefficient for the second lag is positive and statistically significant. This means that environmental taxes, which are less pervasive than energy ones, have a lagged but positive effect on economic competitiveness without any negative side-effect in the very short run.

Considering the second macro-sector, related to *medium-high technology* content, energy and environmental taxes are instead showing a quite different picture. Here energy regulation seems to slightly reduce competitiveness but coefficients are not sufficiently statistically robust for the second lag. In this case, the scarce relevance of

[23] We may also consider that the medium-high tech sector coincides with the largest part of mechanical equipment production, which has faced the strongest demand-pull effect due to the rapid industrialization experienced by new EU States.

environmental taxes in explaining export performances, though it is not in favour of the PH, it is on the other hand not supporting a 'neoclassic' trade off between policy interventions, and consequential compliance costs, and economic performance either. Behind the scene, we may reason around possible negligible net effects deriving from, for instance, both increases in value/productivity (economic, environmental) and in production costs that keep constant the 'competiveness' element deriving from environmental policy.

Evidence slightly changes when analysing *medium-low and low technology sectors*. For *medium-low technology* sectors, we signal that energy taxes are significant, with a positive coefficient (one year lag). Negative effects of energy taxes that we previously highlighted here fade away. This is a relevant result if we think that medium low technological sectors are those characterised by quite high energy intensity, corresponding to the sectors included in the Emission Trading Scheme (ETS) in the European Union (EU). Energy taxes act as levers of higher competiveness through the activation of potential efficiency improvements at production level also in the short run. We can reinforce the empirical evidence of an inducement effect, as far as where the impact of an environmental regulatory framework is immediate and stronger, the inducement effect on production cost and innovative reaction by firms is also larger.

On the contrary, pure environmental taxes do not emerge as a significant driver of the export dynamics. It is probably their lower weight with respect to energy taxes, and their even decreasing share on GDP in the recent history of some EU countries, that leads to a negligible statistical effect. Apart from its relative importance in absolute terms, the great advantage of energy taxation over the other environmental regulation tools relies on its pervasiveness. As energy is still a necessary and hardly substitutable input in the production function, as far as its price elasticity is low, the (negative) impact on average production costs in the very short run is higher. At the same time, its economic relevancy explains the strong innovative reaction by firms whose medium-term advantages in inventing (and adopting) energy-efficient technologies are larger than short-term costs.

As regarding to the *low-tech sector*, it is the only sector where environmental taxation play a major role in respect with energy taxes. We may provide two complementary explanations for this evidence. Manufacturing sectors in this aggregate (mostly food industry and textiles) are relatively more constrained by environmental regulation than energy tax, due for instance quality and standards control for health sanitary reasons, where the EU is rather efficient in upgrading standards and rule for food safety and more generally for consumers protection. The second explanation is related to the relatively less energy intensity of these sectors compared to the first three.

4.1.3 Innovation drivers

The stock of knowledge proves to positively affect export dynamics with both a simultaneous effect and one year lag: both the size and the significance of the coefficient are not negligible at all for *high tech*, though interestingly decreasing over time[24]. As long as some innovation efforts is induced by (environmental and/or innovation) policy, this may constitute an indirect second level benefit arising out of regulatory efforts in environmental and related fields (energy, innovation, industrial policy).

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[24] We note that two years lagged patents are related to a negative coefficient. We interpret it as an effect of innovation activity, captured by patents, that fades away with time. In order to keep constant and increase competiveness, a continuous effort on the innovation arena is needed, mostly within the high tech class of sectors.

Moving down along the sector technological ladder, for the *medium-high-tech* sector, lagged innovation covariates also confirm quite the same statistical significance, with a strong economic significance also in the 'simultaneous' covariate, that shows a coefficient fairly higher than unity in this case. Finally, the *low tech sector* presents again high significance for simultaneous and one year lagged patents, as already noted for other technology categories. Innovation intensity as captured by knowledge stock based on patents number positively shows fairly robust evidence across the four technological cases.

4.2 Green exports: the weak PH

4.2.1 Structural results

The results we comment on below come from the estimation of eq. (3) where the *k-th* sector is the export flows for the aggregate "environmental goods" as early defined in par. 3. Environmental actions by private firms are modelled by using number of EMS, R&D and patenting as innovation keys, and pollution abatement current expenditures (PACE) [25], while public policies are captured by environmental and energy levers as well as public expenditures in environmental R&D.[26]

As regarding to private actions (Table 2), the two lags of the dynamic panel estimations is the proper structure. It is worth noticing that the coefficient value for the second lag is lower comparing to the strong PH where persistency over time seems to be stronger. This difference is a sign of different role of sunk costs in trade decisions by firms, considering that among environmental goods there are many products whose export flows have increased rapidly only in very recent years.

Mass is again often significant, as long as technological capabilities of the importing country, which turns to be statistically robust with a negative sign as expected. As a matter of fact, in this case technological capabilities of the importing countries play the role of barriers to trade. To some extent, as high endowment of a technological capabilities is positively correlated with a higher demand for environmental goods, we may interpret this result as the higher capacity to satisfy demand for environmental goods by domestic production rather by imports. Nonetheless, the definition of technological capabilities as the ARCO index is so general that it should be interpreted as a control rather than a normative attribute.

As far as temporal dummies are concerned, only ETS, capturing years 2005-2006, is here significant; the positive sign of the coefficient cannot probably be stretched to support an evidence of a correlation between ETS introduction and competiveness. It may be that the positive trade and economic cycle of 2005-2006 at world level and the increasing emphasis on green technologies and green investments are captured by this dummy.

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[25] For comparison with international studies (Hamamoto, 2006), we have tested - as sensitivity analysis – the role played by private actions (PACE and EMAS) at sector level (HP 1c and 5).

[26] We have also tested private actions in the strong Porter hypothesis estimations, but results are not robust as expected. The absence of relevant correlation may be well explained by considering how narrow are such private intervention (as a sort of niche strategy for selected firms) with respect to with the broad range of manufacturing goods classified in the four technology-distinguished macro-sectors.

4.2.2 Environmental policy and innovation

As far as the input innovation (R&D factors), public general R&D expenses (one lag) turn out to be highly significant (in its size as well), while specific environmental R&D lagged one year does not. The same comments we provided for energy and environmental taxes may apply in comparing total and environmental R&D shares effects. In Tables 2 and 3 the one lag structure of both innovation and environmental dimensions seems to be more efficient, thus reducing endogeneity while not producing over-identified instruments.

Regarding patenting activities (one lag), the size of the coefficients is similar to what observed for (specific) patent intensity for different 'technological' classes. It is of interest to note that the statistical significance is to some extent influenced by the introduction of other complement/substitute green export drivers in the regression. For example, patents effectiveness in spurring green exports is undermined by PACE

We believe that if sustainability strategies – more likely to occur in high value sectors or in large equity firms (Ziegler et al., 2007) – are needed as bottom up drivers, policy actions is also necessary as top-down levers. Sustainability strategies (such as EMS adoption or CSR) are adopted by very innovative firms – within innovative intense sectors - playing on the innovation frontier or even beyond, thus anticipating social needs and technology adoption.

Complementary to technological innovations at input or output levels, we tested the potential effect of organizational innovations – EMS - which may increase the exported product value. We do not find any significant effect. EMS has shown a quite strong increase in its diffusion recently. The problem may lie either on a low substantial over formal effectiveness of EMS or on its high diffusion, which is heterogeneous across countries. Germany is the absolute leader and massively exporting (green) products. Nevertheless, statistical regularities do not conform to such outlier case in the EU.

Results of specifications that account for the effects of policies such as energy and environmental taxes and environmental R&D expenditures do reinforce empirical evidence on the weak version of the PH.

As far as energy taxes are concerned, the covariate shows a coefficient which is significant from both an economic and statistical points of view, when it is included as long as patents and environmental R&D. Thus it seems to weight more than patents in determining green competitive advantages, supporting with such evidence a fairly robust 'weak Porter idea' of the relationship between policy / regulatory burdens and green based economic performances. Recalling the general necessary conditions about environmental regulation setting stressed by the PH, when policies are market-based (as energy taxes are), internationally homogeneous (and it is also the case), and widely diffused, their pervasiveness ensures also their efficacy, starting an inducement effects on the technological pattern and on the overall economic competitiveness.

The only case where energy taxes are statistically overwhelmed is when (public) R&D is included; this fact confirms that the relative ranking favours R&D as an engine factor of competiveness, reminding to everybody that if on the one hand R&D is not sufficient, since it needs to be complemented by the development of core competencies, synergies between technological, organizational and human capital, complementarity between R&D and human capital.

Table 2 – Trade dynamics for environmental goods, private environmental actions

	(1)	(2)	(3)	(4)	(5)	(6)
$Export_{ij(t-1)}$	0.54***	0.22**	0.51***	0.463***	0.37***	0.60***
	(4.30)	(2.03)	(3.80)	(5.19)	(3.71)	(4.97)
$Export_{ij(t-2)}$	0.04*	0.03	0.04*	0.045**	0.06***	0.03
	(1.92)	(1.43)	(1.75)	(2.34)	(3.06)	(1.41)
$Distance_{ij}$	-0.26	-0.59	0.16	-0.075	-0.50	0.09
	(-0.70)	(-0.75)	(0.31)	(-0.29)	(-1.48)	(0.48)
$Border_{ij}$	-4.32	8.75	-4.05	-1.609	-1.30	0.00
	(-0.79)	(0.63)	(-0.54)	(-0.48)	(-0.40)	(0.00)
Land $Area_j$	-0.28	0.24	-0.16	-0.107	-0.10	-0.18
	(-1.08)	(0.32)	(-0.34)	(-0.51)	(-0.25)	(-0.67)
$Landlock_j$	2.79**	0.51	1.18	2.160***	1.72	2.25*
	(2.19)	(0.20)	(0.83)	(2.60)	(1.10)	(1.71)
$Mass_{ijt}$	0.36**	0.72**	-0.02	0.261**	0.50***	0.11
	(2.31)	(2.18)	(-0.10)	(2.38)	(3.15)	(1.00)
$Similarity_{ijt}$	0.15	-0.69*	0.00	0.102	0.31	0.24
	(0.54)	(-1.93)	(-0.01)	(0.68)	(1.49)	(1.45)
Rel. $Endow_{ijt}$	0.16	-1.22***	0.62*	0.107	-0.21	0.19
	(0.66)	(-2.96)	(1.77)	(0.95)	(-1.03)	(1.58)
Firms Het. $_{ijt}$	0.01	1.14	-0.50	-0.198	-0.35	-0.67***
	(0.03)	(1.52)	(-1.42)	(-0.76)	(-1.38)	(-2.77)
Mills $Ratio_{ijt}$	0.00	0.02	0.02*	0.010*	0.01	0.01**
	(-0.03)	(0.65)	(1.77)	(1.77)	(1.35)	(2.41)
$Knowl_{jt}$	-1.84***	-0.97	-1.41**	-0.982**	-0.47	-0.25
	(-3.18)	(-1.50)	(-2.19)	(-2.31)	(-1.16)	(-0.64)
$Emas_{i(t-1)}$	0.04	-0.10*	0.06			
	(0.70)	(-1.67)	(1.28)			
$Pace_{i(t-1)}$				0.267***	0.18*	0.06
				(2.97)	(1.77)	(0.92)
$Knowl_{iPAT(t-1)}$	0.08			0.132**		
	(0.66)			(2.37)		
$Knowl_{iR\&D(t-1)}$		1.63***			0.40**	
		(3.44)			(2.51)	
$Knowl_{iR\&Denv(t-1)}$			0.06			0.05
			(0.69)			(0.91)
Enl	0.05	0.22***	0.03	-0.002	-0.01	-0.05
	(0.76)	(2.86)	(0.44)	(-0.03)	(-0.11)	(-0.75)
Euro	-0.09	0.01	-0.05	-0.068	-0.07	-0.06
	(-1.50)	(0.09)	(-0.90)	(-1.36)	(-1.34)	(-1.17)
Ets	0.09*	0.16***	0.09*	0.101***	0.12***	0.10***
	(1.86)	(3.30)	(1.77)	(3.00)	(3.06)	(2.84)
Oecd	Yes	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
No Obs.	15333	14447	15333	15453	14567	15453
Wald F-test	2974.69	1432.26	1529.36	4268.83	3714.12	6458.87
AR (1)	-5.67 (0.00)	-4.83 (0.00)	-5.25 (0.00)	-7.07 (0.00)	-5.91 (0.00)	-6.34 (0.00)
AR (2)	1.56 (0.12)	0.43 (0.67)	1.38 (0.17)	1.52 (0.13)	0.77 (0.44)	2.14 (0.03)
Hansen test	35.8 (0.15)	29.94 (0.37)	34.28 (0.19)	34.47 (0.15)	30.36 (0.30)	35.08 (0.14)

*Notes: Two step robust specification has been used. Robust t-statistics in absolute value are reported in parenthesis. *, **, *** significant p-value at the 10%, 5%, 1%, respectively. AR(1) and AR(2) are tests – with distribution N(0, 1) – on the serial correlation of residuals. Hansen Chi-sq test for overidentification of restrictions (number of instruments)*

Table 3 – Trade dynamics for environmental goods, public environmental regulation

	(1)	(2)	(3)	(4)	(5)	(6)
$Export_{ij(t-1)}$	0.56***	0.42***	0.55***	0.26***	0.26***	0.35***
	(6.30)	(5.11)	(5.55)	(3.94)	(3.88)	(4.43)
$Export_{ij(t-2)}$	0.03*	0.04**	0.04*	0.07***	0.05***	0.06***
	(1.74)	(2.37)	(1.84)	(4.08)	(2.70)	(3.15)
$Distance_{ij}$	0.05	-0.16	0.20	0.03	-0.44	0.06
	(0.30)	(-0.75)	(0.94)	(0.16)	(-1.39)	(0.28)
$Border_{ij}$	-2.28	1.73	1.29	0.39	1.30	0.96
	(-1.18)	(0.54)	(0.59)	(0.15)	(0.35)	(0.32)
$Land\ Area_j$	-0.31*	0.24	-0.37	-0.28	-0.12	-0.16
	(-1.77)	(0.74)	(-1.25)	(-1.19)	(-0.27)	(-0.43)
$Landlock_j$	2.13**	1.28	1.17	1.72*	1.48	2.13*
	(2.22)	(0.83)	(0.91)	(1.84)	(0.78)	(1.66)
$Mass_{ijt}$	0.12	0.17	0.14*	0.37***	0.56***	0.22
	(1.64)	(1.16)	(1.71)	(3.97)	(2.96)	(1.55)
$Similarity_{ijt}$	0.24*	-0.13	0.22	-0.04	0.05	0.23
	(1.87)	(-0.60)	(1.44)	(-0.23)	(0.18)	(1.07)
$Rel.\ Endow_{ijt}$	0.34***	-0.21	0.24*	0.03	-0.37	0.10
	(3.15)	(-1.32)	(1.78)	(0.22)	(-1.58)	(0.61)
$Firms\ Het._{ijt}$	-0.43**	-0.44**	-0.72***	-0.39	-0.10	-0.69***
	(-2.38)	(-2.11)	(-3.00)	(-1.40)	(-0.41)	(-3.02)
$Mills\ Ratio_{ijt}$	0.01	0.01**	0.02***	0.02***	0.01	0.01***
	(0.81)	(2.21)	(3.54)	(3.97)	(1.55)	(2.57)
$Knowl_{jt}$	-0.47	-0.46	0.20	-0.14	-0.57	0.59*
	(-1.24)	(-1.17)	(0.59)	(-0.40)	(-1.49)	(1.79)
$Energy\ Tax_{i(t-1)}$	0.55**	0.14	0.59***			
	(2.42)	(0.58)	(2.70)			
$Environ.\ Tax_{i(t-1)}$				0.26**	0.17**	0.07
				(2.01)	(1.96)	(0.91)
$Knowl_{iPAT(t-1)}$	-0.01			0.18***		
	(-0.29)			(2.99)		
$Knowl_{iR\&D(t-1)}$		0.40***			0.64***	
		(3.40)			(4.26)	
$Knowl_{iR\&Denv(t-1)}$			0.11*			0.12**
			(1.83)			(2.21)
Enl	0.00	-0.01	-0.01	0.05	0.06	-0.05
	(0.01)	(-0.21)	(-0.25)	(0.86)	(1.10)	(-0.94)
Euro	-0.07	-0.03	-0.08	-0.12**	-0.07	-0.04
	(-1.42)	(-0.68)	(-1.52)	(-2.39)	(-1.19)	(-0.74)
Ets	0.13***	0.16***	0.09***	0.07**	0.09**	0.07*
	(4.40)	(4.12)	(2.68)	(2.08)	(2.16)	(1.79)
Oecd	Yes	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
No Obs.	15453	14567	15453	15453	14567	15453
Wald F-test	7359.11	5862.96	6079.38	4267.31	3806.68	4184.3
AR (1)	-7.7 (0.00)	-7.23 (0.00)	-7.05 (0.00)	-7.48 (0.00)	-7.19 (0.00)	-7.21 (0.00)
AR (2)	2.29 (0.02)	1.51 (0.13)	2.04 (0.04)	-0.32 (0.75)	0.31 (0.75)	0.64 (0.52)
Hansen test	34.7 (0.15)	30.1 (0.31)	35.48 (0.13)	39.02 (0.06)	31.99 (0.23)	38.84 (0.07)

Notes: Twos step robust specification has been used. Robust t-statistics in absolute value are reported in parenthesis.
, **, * significant p-value at the 10%, 5%, 1%, respectively. AR(1) and AR(2) are tests – with distribution N(0, 1) – on the serial correlation of residuals. Hansen Chi-sq test for overidentification of restrictions (number of instruments).*

Somewhat differently, when analysing environmental tax effects, their economic significance is lower with regard to energy taxes, but it is consistent with previous results. Thus, environmental taxes, generally weaker in their effects throughout our analyses, do not trade off with patents and general R&D effects, but with specific environmental R&D effects. This outcome could be plausible: the closer the factors are (as environmental taxes and environmental public R&D), the higher can be the likelihood of crowding out effects. Extensive and specific levers instead prove to be highly 'complementary': they both contribute to the enhancement of green competitive advantages.
In the end, with some different evidence when diverse factors are jointly tested, that we may explain on the basis of their quite dissimilar 'fiscal' weights, energy and environmental taxes effectively contribute to the explanation of green export performances. At least in this specific definition of performances, we support to a greater extent the weak side of the PH, with some additional effects.

5. Conclusions

We have shown that over a recent and fairly long period of time, overall evidence in support of the strong and weak Porter hypotheses can be found for the EU15 by focusing on sector export dynamics. Environmental policy actions seem not to undermine EU competiveness, confirming other recent evidence obtained by macro econometric models. We provide new and rich results by disaggregating effects across high tech – low tech sectors, by exploiting diverse innovation and policy related drivers, and finally by focusing down on green export performances. Overall, the effect of energy and environmental taxes (to a lesser extent) is not in conflict with export performances. In some cases we observe positive relationships, in other negligible, and when negative they seem to be circumscribed to the very short run effect, in line with theoretical expectations.
This could be very good news: such interventions, that may be structured in different ways according to different environmental policy / ETR features do not bring about indirect costs though depressed economic performances, at least on the export component. On this basis it becomes more likely that environmental and regulatory pressures increase their social acceptability provided that the sum of (non market, health) benefits caused by emission reductions minus costs (tax burden, compliance costs, innovation investments, among the others) is going to be positive with higher probability.
The weak PH seems to confirm the possibility of 'green competiveness' strategy for the EU. Environmental and energy taxes, regulatory effects captured by PACE, public R&D and patenting activities all generate enhancement of green competitive advantages, after controlling for structural trade related, geographical and structural time related effects. R&D is arising as leader in the ranking, but with patents, energy taxes and also environmental taxes playing their role. Overall, the weight of 'public' levers (regulations, taxes) is stronger than that of private innovations, but the balance between the two spheres is less uneven. Both public and private actions are complementary needed to drive (green) economic performances up.
On the 'strong side' of the tale, we also find that environmental policy actions eventually bring about negative performances in the very short run, but correlates positively to competiveness in the medium run. More important, high tech and medium tech sectors respond positively to energy and environmental taxation, and also

medium tech and low technology sectors are not negatively impacted; they respectively even respond positively to energy and environmental taxes. The correlations we find are coherent with sector technological features. Across high-low tech sectors, innovation – patenting – is always significant with a robust and interestingly positive correlation that fades away with time, in line with the theoretical expectations. The joint coherence of the story we draw out is that policy effects are positively increasing over time, with their eventual costs limited to the very short run, while innovation effect fade away making necessary continuous investments to maintain competitiveness.

The message is thus that robust (green) exports could drive the EU towards a new frontier of competitive advantage, sustained by complementary private (innovation) of leading sectors investments and public (tax) actions. Germany and other countries are already on the edge but eco-innovation advantages must be strengthen and reconciled with policy actions: environmental Porter based leadership should correspond with industrial green leadership and higher competiveness in the end, that through FDI and investments can be diffused to transition and emerging economies.

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APPENDIX

Table A1 – Classification of industrial sectors and concordance with patents fields

Macro sector	Sector	ISIC Rev. 3	NACE	PATENTS FIELD*
High-technology industries (SEC-1)	1. Aircraft and spacecraft	353	35.3	43
	2. Pharmaceuticals	2423	24.4	13
	3. Office, accounting and computing machinery	30	30	28
	4. Radio, TV and communications equipment	32	32	34-35-36
	5. Medical, precision and optical instruments	33	33	37-38-39-40-41
Medium-high-technology industries (SEC-2)	6. Electrical machinery and apparatus	31	31	29-30-31-32-33
	7. Motor vehicles, trailers and semi-trailers	34	34	42
	8. Chemicals excluding pharmaceuticals	24 excl. 2423	24 excl. 24.4	10-11-12-14-15-16
	9. Railroad equipment and transport equipment	352 + 359	35.2-35.4-35.5	44
	10. Machinery and equipment, others	29	29	21-22-23-24-25-26-27
Medium-low-technology industries (SEC-3)	11. Building and repairing of ships and boats	351	35.1	45
	12. Rubber and plastics products	25	25	17
	13. Coke, refined petroleum products and nuclear fuel	23	23	09
	14. Other non-metallic mineral products	26	26	18
	15. Basic metals and fabricated metal products	27-28	27-28	19-20
Low-technology industries (SEC-4)	16. Manufacturing, others	36	36	46
	17. Wood, pulp, paper, paper prod., print. and pub.	20-21-22	20-21-22	06-07-08
	18. Food products, beverages and tobacco	15-16	15-16	01-02
	19. Textiles, textile products, leather and footwear	17-18-19	17-18-19	03-04-05

*Notes: * The figures reported in column "Patent fields" refer to the 46 fields where patents are classified by using the full list of IPC codes for each patent field described in the Appendix of Schmoch et al. (2003) in order to provide a correspondence between IPC codes and ISIC Rev.3 industrial sectors.*

Table A2 – Correlation Matrix

	Mass	Similarity	Rel Endow	Inn_j	Ene. Tax_i	Env Tax_i	$Emas_i$	$Pace_i$	$RDEnv_i$	RD_{TOTi}	Pat_{TOTi}	Pat_{SEC1i}	Pat_{SEC2i}	Pat_{SEC3i}
Similarity	-0.24													
Rel Endow	0.26	-0.28												
Inn_j	-0.24	-0.16	0.03											
Ene. Tax_i	0.22	-0.14	-0.05	-0.07										
Env Tax_i	-0.49	0.28	0.05	0.02	-0.05									
$Emas_i$	-0.12	0.08	0.03	0.20	-0.08	-0.15								
$Pace_i$	-0.05	0.03	-0.02	0.02	0.16	-0.08	0.38							
$RDEnv_i$	0.25	-0.15	-0.02	0.00	0.09	-0.09	0.04	0.13						
RD_{TOTi}	-0.01	0.00	0.07	0.26	-0.19	-0.15	0.37	0.14	0.22					
Pat_{TOTi}	0.14	-0.07	0.12	0.27	-0.24	-0.12	0.34	0.19	0.15	0.87				
Pat_{SEC1i}	0.56	-0.30	0.08	0.16	0.03	-0.40	0.13	0.04	0.26	0.62	0.81			
Pat_{SEC2i}	0.59	-0.32	0.06	0.12	0.04	-0.49	0.17	0.17	0.34	0.62	0.79	0.96		
Pat_{SEC3i}	0.58	-0.32	0.07	0.12	-0.01	-0.46	0.20	0.12	0.29	0.60	0.80	0.98	0.99	
Pat_{SEC4i}	0.60	-0.32	0.07	0.11	0.02	-0.47	0.20	0.11	0.28	0.57	0.76	0.96	0.98	0.98

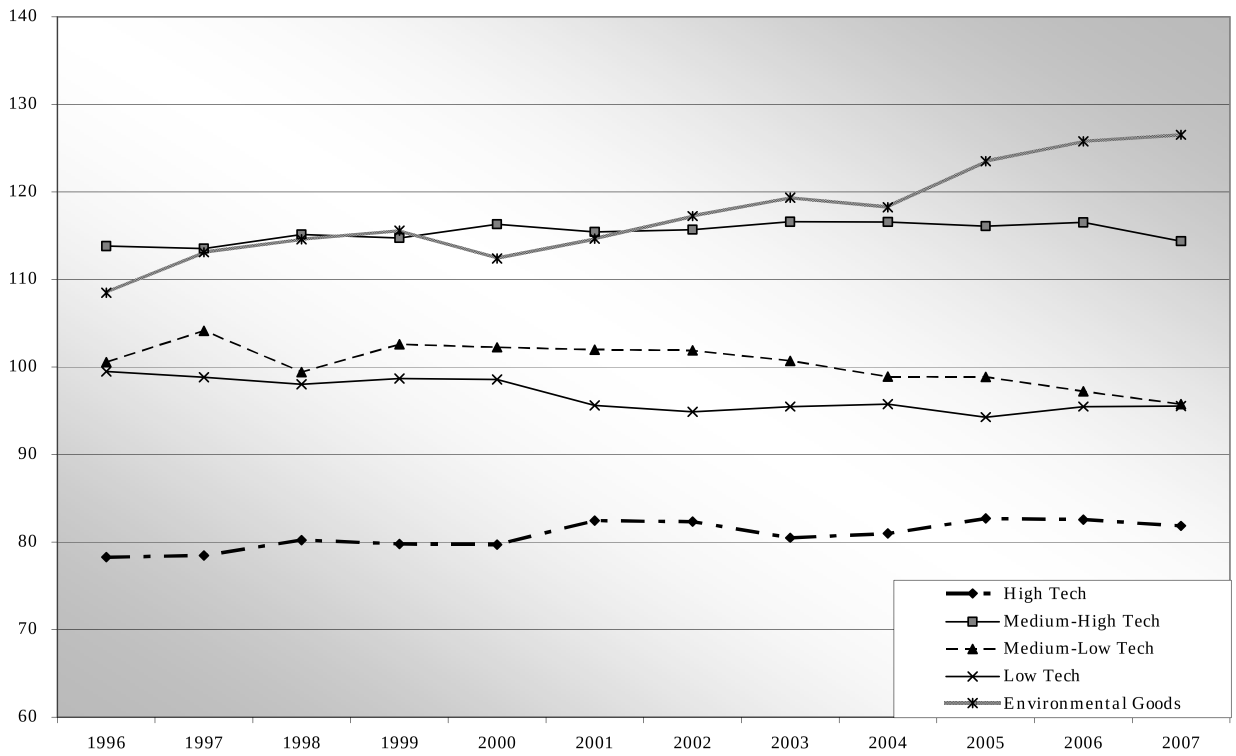
Table A3 – Descriptive statistics

Variable	No Obs.	Mean	Std.Dev	Min	Max
Mass	22,400	27.26	1.00	25.16	30.38
Similarity	22,400	-2.11	1.33	-7.23	-0.69
RelEndow	22,232	10.08	0.95	2.27	14.90
Innj	21,798	-2.25	1.44	-8.27	-0.05
Ene.Taxi	24,192	1.56	0.21	1.11	2.13
EnvTaxi	24,192	0.71	0.60	-0.45	2.04
Emasi	23,328	-9.09	1.56	-13.64	-6.58
Pacei	24,192	-1.05	0.52	-2.12	-0.03
RDEnvi	24,192	-4.16	0.43	-4.61	-3.22
RDToti	21,024	0.49	0.52	-0.93	1.45
PatTOTi	24,192	7.05	1.94	1.61	10.72
PatSEC1i	24,192	5.97	1.89	0.00	9.42
PatSEC2i	24,192	6.15	1.92	1.39	10.02
PatSEC3i	24,192	5.30	1.82	0.55	8.71
PatSEC4i	24,192	4.64	1.68	0.00	7.79

Table A2 – Definition of variables and research hypotheses

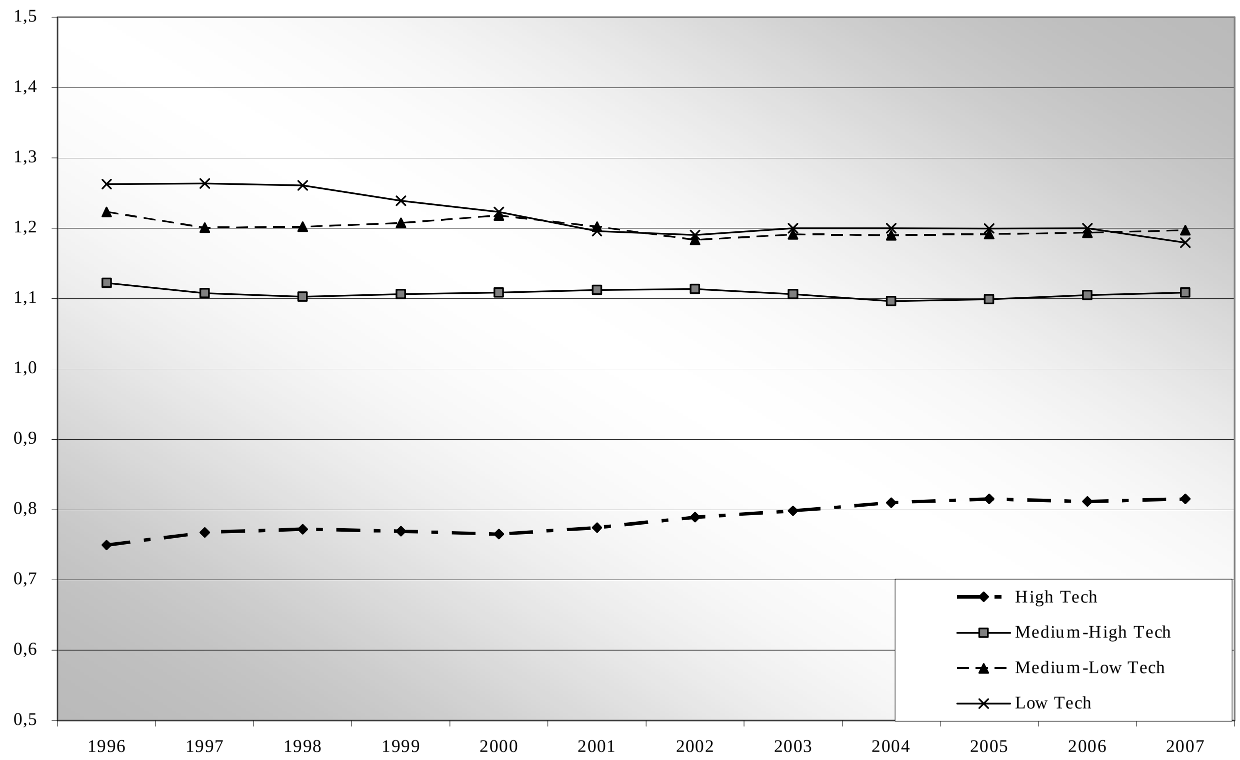
Variable	Definition	Source		Research hypotheses
	Dependent variables			*Expected signs*
$Export_{ijt}$	Total export flows in current US$ from countries *i* to countries *j* at time *t*, for 4 manufacturing macro-sectors (High-Tech; Medium-High-Tech; Medium-Low-Tech; Low-Tech, as defined in Table A1) and for environmental goods (full list of HS1996 codes in Steenblick, 2005), separately. (*time variant, sector specific*)	UNCTAD-COMTRADE		
	Standard gravity (GRAV)			
$Distance_{ij}$	Bilateral geographic distances from countries *i* to countries *j* (*time invariant, sector invariant*)	CEPII		-
$Border_{ij}$	Geographic contiguity between country *i* and *j* (*dummy variable time invariant, sector invariant*)			+
Land $Area_j$	Natural logarithm of land area of country *j* sq. km (*time invariant, sector invariant*)			Any
$Landlocked_j$	Landlocked countries *j* dummy variable (*time invariant, sector invariant*)			Any
$Mass_{ijt}$	$mass_{ijt} = \ln(GDP_{it} + GDP_{jt})$ (*time variant, sector invariant*)	World Bank WDI		Any
$Similarity_{ijt}$	$sim_{ijt} = \ln\left[1 - \left\lvert\left(\frac{GDP_{it}}{GDP_{it}+GDP_{jt}}\right)^2 - \left(\frac{GDP_{jt}}{GDP_{it}+GDP_{jt}}\right)^2\right\rvert\right]$ (*time variant, sector invariant*)			+
Rel. $Endow_{ijt}$	$endw_{ijt} = \left\lvert \ln\left(\frac{GDP_{it}}{POP_{it}}\right) - \ln\left(\frac{GDP_{jt}}{POP_{jt}}\right)\right\rvert$ (*time variant, sector invariant*)			Any
	Public Environmental policies / private environmental action			
Ene-Tax_{it}	Energy tax revenues as percentage of total revenues (*time variant, sector invariant*)	EUROSTAT	HP1a	Neoclassic and Porter like perspectives tested: eventually Negatively related to economic performances in the short run, potential positive effects in the medium run: negligible effects if forces compensate Potential sector specific effects when tested on high tech-low tech
Env-Tax_{it}	Environmental tax revenues as percentage of total revenues(*time variant, sector invariant*)		HP1b	
$Pace_{it}$	Pollution abatement and control expenditures as percentage of GDP (*time variant, sector invariant*)		HP1c	
	Innovation measures: public and private techno-organizational factors			
$Knowl_{iPATt}$	$INN_{it}^{k} = \sum_{s=0}^{t} PAT_{is}^{k} e^{[-\beta_1(t-s)]}$ Stock of knowledge function calculated on patents number (*time variant, sector specific*)	OECD- EUROSTAT	HP2	Positive effects possibly fading away over time
$Knowl_{iR\&Dt}$	Gross expenditures for R&D as percentage of GDP (*time variant, sector invariant*)		H3a	
$Knowl_{iR\&Denvt}$	Public environmental R&D efforts as percentage of GDP. (*time variant, sector invariant*)		H3b	
$Knowl_{jt}$	ARCO index calculated as eq. (7) (*time variant, sector invariant*)		HP4	
$Emas_{it}$	Number of Eco-Management and Audit Scheme initiatives by private firms as percentage of GDP (*time variant, sector invariant*)	EUROSTAT	HP5	

Figure A1 – RCA on exports by technology sectors and environmental goods (EU15)



Source: own calculations on UN-COMTRADE data.

Figure A2 – TRCA on patent stocks by technology sectors (EU15)



Source: own calculations on OECD-PATSTAT data.