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Summary
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Keywords: Environmental Policies, Porter Hypothesis, Technological Innovation, Export Performances, Gravity Model, European Union

JEL Classification: F14, O14, Q43, Q56

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

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Abstract

This paper aims to explore how the competitiveness of the EU economy, here captured by export dynamics over 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 five aggregated manufacturing sectors classified by their technological or environmental content using a dynamic panel data estimator applied to a theoretically-based gravity model.
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1. Introduction

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

A more general framework in 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 specific effects generated by environmental regulation on trade comparative advantages, two prevailing perspectives, which are often conflicting but not necessarily, are the pollution haven hypothesis (Letchumanan and Kodama, 2000; Levinson, 2010; Muradian *et al.*, 2002) and the Porter hypothesis (Porter and van der Linde, 1995; Jaffe and Palmer, 1997; Wagner, 2006). According to Copeland and Taylor (2004), environmental policy enters 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 domestic firms facing higher productive costs. This could lead to delocalization of production towards countries with a relatively lower burden of environmental regulation.

As far as the Porter hypothesis (PH) is concerned,[1] up until the development of such a framework, the general idea was that the fulfilment of environmental regulation would be likely to reduce the competitiveness of the involved sectors/firms. However, on the contrary, the PH seems to test the potential complementarities and (private) beneficial effects of properly designed environmental regulations which are likely to emerge in a dynamic context with innovation and

[1] 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 in the real world where externality correcting taxes and regulations face costs and constraints that require the use of multiple instruments to achieve efficiency and effectiveness (Christiansen and Smith, 2009).. To some extent, evolutionary economics has recently emphasised that traditional economic approaches are inappropriate for dealing with the dynamics of structural and adaptive changes especially for environmental issues (Kemp, 1997; Nill and Kemp, 2009; Rammel and van der Bergh, 2003; van der Bergh, 2003; van der Bergh and Gowdy, 2000; van der Bergh *et al.*, 2007).

environmental strategies which co-evolve (Mazzanti and Zoboli, 2009).

Export dynamics and technology diffusion play a strong role here. While it may be true that some growth patterns are unsustainable from a national point of view, when the decoupling process of environmental damage from growth could be an over-optimistic outcome along a consumption based perspective, 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), thus creating the conditions for a race to the top instead of a race to the bottom through the development and globalization processes. 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.

Corporate social responsibility (CSR) behaviour (Portney, 2008) and race to the top innovation dynamics can be present in economic/institutional frameworks characterized by regulated markets, wherein more innovative firms take a long run 'beyond compliance' perspective to profit making and thus lead a social investment strategy. Innovative firms and more innovative sectors go beyond the edge of technological frontiers, changing and enhancing structural competitive advantages. Institutional, economic, trade and policy frameworks contribute to the creation and necessary diffusion of leading innovations (Rennings and Smidt, 2009).

As outlined by Jaffe *et al.* (1995), the PH should be broken down into separate versions: the strong version claims that environmental regulation enhances economic performance, at least in the medium run, for the economy as a whole; the weak version predicts that a stringent regulatory framework positively impacts only on the 'green side' of the economy.

The empirical studies on the PH have not been successful so far in finding robust support for the strong argument whereas they have mostly been successful in the weak argument when evidence is based on specific environmental industries (Costantini and Crespi, 2008; Murty and Kumar, 2003). Analogously, the main contributions addressing the impact of environmental regulation on technological innovation using patent data (Jaffe and Palmer 1997; Lanjouw and Mody, 1996) have not found unanimously robust evidence. Some evidence on the strong version has emerged but it remains often limited to case study evidence or cross section analysis based on survey data which are structurally plagued by regional idiosyncrasies (Triebswetter and Wackerbauer, 2008), allowing weak generalisation at EU level. Nevertheless, more recently, there has been increasing empirical evidence to support the argument that stringent environmental policies lead to technological innovation specifically in the energy sector (Johnstone *et al.*, 2010; Walz *et al.*, 2008).

There is also increasing consensus on the potential win-win effects deriving from well combined environmental and innovation strategies, both on the private and public side (Jaffe *et al.*, 2003, 2005). 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 consistent with environmental goals. In this respect, the use of an appropriate mix of innovation 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 the implications arising from macro models with micro-economic details (Mazzanti and Montini, 2010). Nevertheless, economic effects have received less attention from the empirical literature with regard to innovation and environmental performances. ?Within it, the analysis of export dynamics for technology-distinguished sectors including green manufacturing goods is a relatively new research field.

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; Edenhofer and Stern, 2009). Green recovery measures should deal with two problems - the economic and climate crises – simultaneously, even though the overall impression is that direct intentional action on green growth and climate change, as well as R&D, still have a limited role in the national recovery plans of EU countries (Saha and Von Weizsacker, 2009). The greening of exports may lead to structural competitive advantages, but it needs to be supported by coevolving innovation and environmental policy instruments in the transition towards sustainable pathways (Geels and Schot, 2007). Furthermore, the focus on trade and competitiveness has a specific relevance in the EU, given the historical role played by the region, led by major export-driven countries such as Germany and Italy, and the current need to reshape EU trade advantages when faced with new challenges from Asian countries. The environmental innovation frontier is one of the leading strategies. Many actions have been implemented and others proposed. Nevertheless, evidence on the competitiveness effects of environmental innovation and policy actions is scarce.[2]

In this respect, according to Parry (2009) for the US and Andersen and Ekins (2009) for the EU, the implementation of carbon taxes and/or auctioned permits is a fruitful way to reconcile environmental and economic performances in this recession where Environmental Tax Reforms (ETR) can be shaped on a real 'policy based' target perspective, including competitiveness scopes. In particular, estimates by Barker *et al.* (2007) and Pollitt and Chewpreecha (2009) provide evidence discarding fears of potential negative effects associated with ETR and climate actions on employment, income distribution, economic growth and exports performance.

Nonetheless, some cautions on simulation results should be adopted, or in other words, some robustness checks based on past observed phenomena should be added to confirm these favourable outcomes and hypotheses. 'Sustainable' robust export-led economic performance is a way towards to sustainable high-skilled job creation and also a step towards moving away from the low productivity trap most EU countries have experienced and will experience in the post crisis.

Since within this already rich body of literature, empirical evidence on the strong version of the PH is still missing whereas weak PH has only been proved for selected environmental fields, in this paper we try to fill this gap at least in the specific though crucial economic aspect of export competitiveness. In particular, we are interested in specifically understanding how environmental regulation and technological innovation have influenced the economic competitiveness of the EU represented by export dynamics by testing both versions of the PH.

Our first set of research hypotheses (HP1), coherently with a strong PH, regards the effects on competitive advantages of export flows deriving from public environmental policies, distinguished as energy taxes and net environmental taxes. Here, we assume that only pervasive and diffused regulatory instruments play some sort of role in influencing aggregated sectors whereas private (firm-level) actions may not constitute a significant levy for aggregated economic competitiveness. Since the strong PH is under investigation, export flows are related to four macro sectors classified by their technological content (OECD, 2008a) that represent the whole manufacturing sector. Hence, we test whether such effects - if any - on exports are sector specific.

The second set of research hypotheses regards the weak version of the PH, where the environmental regulatory framework should foster export dynamics of industries producing environmental-friendly goods. In this case, we may expect private compulsory and voluntary

2 Among others, 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).

actions (HP2a) – here represented by pollution abatement control expenditures (PACE) and an Environmental Management System (EMS) - to play a role in enhancing economic competitiveness, together with public environmental policies (HP2b), since the overall environmental regulatory framework acts as a lead-user force for creating and feeding an emerging market. Hypotheses are discussed in more detail in the next section.

The rest of the paper is structured as follows. Section 2 presents conceptual and methodological issues of the gravity model, Section 3 comments on outcomes of dynamic panel regressions and Section 4 offers some conclusions.

2. Econometric issues, the model and the dataset

2.1 Recent advancements in gravity models

For the purpose of our analysis, we choose a gravity equation framework taken 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.

Relying on recent contributions on gravity model for trade flows, we have considered three major issues in our empirical model: 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.

With regard to the first issue, according to Anderson and van Wincoop (2003), MRTs should be added to 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 also be represented appropriately for a panel dataset.

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. According to Helpman, Melitz and Rubinstein (2008) (HMR hereafter), 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, a Heckman's two-stage procedure is used to account for selection and heterogeneity biases where some explanatory variables related to the costs of establishing trade flows which affect firms' decisions to export or not are only included in the first stage equation (Wooldridge, 2002).[3]

[3] The two terms coming from first-stage equation are the extensive margins of trade (representing firms heterogeneity) calculated as the predicted probability of trade from country *i* to country *j*, and the intensive margins of trade (representing the selection bias) given by the standard inverse Mills ratio.

The third issue concerns a dynamic specification of trade flows that allows the serial correlation caused by a strong time persistency in trade flows related to the presence of sunk costs to be addressed (Bun and Klaassen, 2002). For this purpose, System GMM proposed by Blundell and Bond (1998) seems to be a proper estimator, making it possible to correct for autocorrelation of residuals while retaining all fixed effects and time invariant variables, unlike a simple GMM estimator. Moreover, Bond and Windmeijer (2002) show that it is more efficient than the Arellano and Bond GMM if the panel has a short time dimension (*T*) and a large number of cross-section units (*N*) and if it includes persistent time series as in a standard panel-based gravity model.

2.2 *The model and the dataset*

Our panel dataset has a large number of cross-section units and a small time dimension and trade flows show strong persistence in the short-run and includes many zero values. The best way to deal with these problems is to adopt the two-stage HMR procedure, with a panel probit estimator for the first stage and a System GMM for the second dynamic equation.

The country sample considered here is made up of 14 *i-th* exporting countries (all EU15 members where Belgium and Luxembourg are merged) and 145 *j-th* importing countries.[4] The time period is 1996 – 2007, and the full sample therefore covers a total of 24,360 observations. The final log-linear equation of our gravity model is as follows:

$$x_{ijt}^{k} = \alpha_i + \delta_j + \tau_{ijt} + \sum_{p=1}^{n} \lambda_p x_{ij,t-p}^{k} + \beta_1 BORDER_{ij} + \beta_2 dist_{ij} + \beta_3 mass_{ijt} + \beta_4 sim_{ijt} + \\ + \beta_5 endw_{ijt} + \beta_6 fhet_{ijt}^{k} + \beta_7 mills_{ijt}^{k} + \beta_8 inn_{i,t-q}^{k} + \beta_9 inn_{jt} + \beta_{10} envreg_{i,t-q} + \phi \mathbf{D} + \varepsilon_{ijt} \tag{1}$$

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

The vector of dependent variables is alternatively expressed by bilateral export flows from country *i* to country *j* at time *t* for five *k-th* sectors representing four distinct macro-sectors and one 'green' sector. In order to estimate 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 described in Table A1 in the Appendix). The weak PH is tested on the fifth sector defined here as an aggregation of all Harmonized System Classification

[4] 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.

codes (HS1996) listed in Steenblick (2005) as environmental goods which are currently subject to specific negotiation in the WTO.[5]

The three modelling concerns described in par. 2.1 are dealt with as follows. The inclusion of time-invariant MRTs suggested by Anderson and van Wincoop (2003) is proxied by country specific fixed effects (a_i and δ_j for exporting and importing countries, respectively) whereas the country-pair specific effect is included as a time-variant variable (τ_{ijt}) as suggested by De Benedictis *et al.* (2005) for a panel version of the model. The dynamics and persistence of the dependent variable which produces autocorrelation bias is captured and the lag structure is endogenously determined ($\sum_{p=1}^{n} \lambda_p x_{ij,t-p}^{k}$). Finally, potential bias due to zero trade flows is reduced by including two terms from the first-stage equation as the extensive margins ($fhet_{ijt}$) and the intensive margins ($mills_{ijt}$) of trade, calculated for each *k-th* sector separately.[6]

The standard variables in a gravity equation are the following. $BORDER_{ij}$ 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). We expect the coefficients for $BORDER_{ij}$ to be positive and those for $dist_{ij}$ to be negative since distances are commonly considered as a proxy of transport costs.

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

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

The larger this measure, the more similar the two countries are in terms of GDP and the greater the expected 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 given by:

$$mass_{ijt} = \ln\left(GDP_{it} + GDP_{jt}\right) \quad (3)$$

A measure of the distance between relative endowment of domestic assets ($endw_{ijt}$) is

[5] 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.

[6] For the sake of simplicity, we have not reported results from first stage probit equations, but they are available upon request from the authors.

approximated by eq. (4) where GDP per capita is a proxy of the capital-labour ratio of each country:

$$endw_{ijt} = \left| \ln\left(\frac{GDP_{it}}{POP_{it}}\right) - \ln\left(\frac{GDP_{jt}}{POP_{jt}}\right) \right| \quad (4)$$

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

We have also included sector-specific variables to represent the role of innovative capacity in explaining trade performance for each sector since there is convincing empirical evidence that cumulative domestic innovation efforts are an important determinant of productivity and competitiveness (Eaton and Kortum, 2002).

The explanatory variable associated with the role of technological innovation for exporting countries ($inn^k_{i,t-q}$) 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.[7] Our data allow patents to be assigned as 4-digit codes of the International Patents Classification (IPC) for inventing industries so that our stock of knowledge function is:

$$INN^k_{it} = \sum_{s=0}^{t} PAT^k_{is} e^{[-\beta_1 (t-s)]} \quad (5)$$

where INN^k_{it} is the knowledge stock in industry *k* for each *i-th* exporting country at time *t*. Here PAT^k_{is} 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 $inn^k_{i,t-q}$ is calculated as the logarithm of the stock for each year.

The stocks allow an overall knowledge production function to be estimated, considering that in most cases the capacity to apply for a patent (international offices such as the European

[7] 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 only interested in investigating the knowledge production process and not the diffusion patterns.

Patents Office, EPO)[8] 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.[9]

It is worth noticing that this disaggregation is only possible for the four sectors related to the strong PH whereas a commonly accepted definition of an environmental patent class is still far from being accepted (OECD, 2008b). For this purpose, we have replaced the sector-specific innovation variable for the green *k-th* sector with public R&D expenditures for environmental purposes, taking into account the broadest definition of environmental protection consistent with the definition of the dependent variable.

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 capability index relying on Archibugi and Coco (2004).[10] 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 as follows:[11]

$$inn_{jt} = \frac{1}{2}\left[\frac{1}{3}\left(\frac{\ln(Tel_{jt})}{\ln(Tel_{\max t})} + \frac{\ln(Internet_{jt})}{\ln(Internet_{\max t})} + \frac{\ln(Electr_{jt})}{\ln(Electr_{\max t})}\right) + \frac{1}{2}\left(\frac{\ln(Edu_{jt})}{\ln(Edu_{\max t})} + \frac{\ln(Fdi_{jt})}{\ln(Fdi_{\max t})}\right)\right] \quad (6)$$

where per capita fixed and mobile telephone lines and Internet subscribers, per capita electricity consumption, secondary gross enrolment ratio and Foreign Direct Investment (FDI) inflows as percentage of GDP are considered.

The final group of covariates ($envreg_{i,t-q}$) refers to several measures of environmental instruments adopted by the *i-th* exporting countries, as energy and environmental taxation, public R&D expenditures for environmental purposes, and private actions played by firms both compulsory (such as environmental protection expenditure as percentage of GDP) and voluntary

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[8] We have only considered EPO applications because since we only consider patents submitted 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 viable inventions.

[9] We have chosen the classification of patent data proposed by Schmoch *et al.* (2003) and Verspagen *et al.* (2004), referring to 46 industrial sectors, classified by using ISIC Rev.3, which are related to the International Patents Classification codes. We have condensed the original 46 sectors into the 4 macro-sectors used for the Annual OECD Technology Scoreboard Report.

[10] 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.

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

such as EMS implementation.[12]

Finally, in order to investigate whether some structural breaks occurred during the time span, we tested a set of dummies for temporal shocks, such as the influence of the EU enlargement process, the adoption of the euro and the entry into force of the European Emission Trading Scheme.[13] A set of geographical dummies was also tested (vector **D** in eq. (1)) in order to catch some potential clustering effects due to regional trade agreements or similar. The only variable retained in the final estimations is related to importing countries belonging to OECD.

3. Empirical evidence

3.1 The drivers of export performances in the strong PH

3.1.1 Structural results

Although 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-sector disaggregation is clearly helpful when disentangling the pure innovation effect related to the specific sector characteristics from an inducement effect produced by environmental regulation stringency.

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

[12] The inclusion in a gravity model of a unilateral dimension as in the case of environmental regulation of *i* countries with no correspondence for the partner countries may produce biased results as an omitted variables problem may arise. We have tested in our model several measures which could proxy the regulatory efforts of importing countries, as CO_2 emissions or energy intensity reduction trends but results do not change substantially while we will lose a large number of observations. We have also thought about using an institutional quality measure as a common variable used in the environment-development literature (Farzin and Bond, 2005) but in this case even more serious problems may arise from the inclusion of an institutional quality distance between *i* and *j* countries as our key variable for the panel first stage probit estimation to compute the extensive and intensive margins of trade. Results reported in our empirical estimations thus omit such variable from the *j* countries side.

[13] 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 according to the standard assumption of the so-called 'announcement effect', corresponding to the date of the European Council meeting of Laeken in December 2001.

>>INSERT HERE TABLE 1<<

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, positively explaining trade dynamics, showing consistent effects across sector classes. 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 factors endowment. As far as *Distance* is concerned, it is significant with a negative expected sign in all cases but high tech; we believe this evidence is coherent with the fact that transport costs are less relevant for higher value and technological intense goods. On the contrary, the *Border* effect is not significant as it has been often found in the related recent literature with sector-specific trade flows.

The fitness of a two stage procedure finds validation from statistical robustness of both *Firms Heterogeneity* and selection bias (*Mills*). It is also interesting to see that heterogeneous firms' behaviours in trade patterns explain export dynamics especially for the high-tech sector, fairly consistently with higher trade sunk costs compared 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 increased competitiveness: in a phase (2003-2007) characterised by strong world trade trends, EU sectors were not penalized by a strong currency. This is consistent with the fact that a strong euro is a penalty from a mere price perspective, but stimulate and force firms in export oriented countries to increase competitive advantages through innovation investments and enhancement in product value, as recent developments in German and Italian trade trends reveal.

We also find a significant coefficient for ETS, and it is worth noting that for those sectors currently excluded from the scheme, ETS seems to enhance export competition, while for medium-high and medium-low sectors, which together include all sectors covered by ETS, a negative effect is shown. Nonetheless, to our opinion this result is far from being conclusive, as a further sector disaggregation and a longer time series are required to infer on the real impact of ETS on firms' competitiveness.

3.1.2 Environmental policies and innovation drivers

As far as the high technology sector is concerned, it is the only one where we find significant and persistent impacts on export dynamics related to both energy – though significance is weaker in this case - and environmental tax levers. More specifically, the one-year lag for environmental taxation shows a positive and significant (also in size) coefficient. This means that environmental taxes, which are less pervasive than energy ones, have a positive effect on economic competitiveness without negative side-effects in the very short run. In addition, though energy taxation is relatively weaker in its effects, the sign of the 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.

If we consider the second macro-sector, related to medium-high technology content, energy and environmental taxes show a quite different picture. Here energy regulation seems to be definitely not significant and environmental taxation slightly – coefficient size and statistical significance are both lower with respect to the high-tech case - reduce competitiveness. This shows that the PH should be scrutinised case by case with detail and that sector/policy instruments heterogeneity matter.

As a proof of the interest of investigating sector specific features and reactions to policies, evidence changes when analysing medium-low and low technology sectors. For the medium-low sectors, we signal that energy taxes are significant with a positive coefficient: this is the most robust evidence of strong PH we here find. This is a relevant result if we consider that medium-low technology sectors are those characterised by quite high energy intensity, corresponding to most sectors included in the Emission Trading Scheme (ETS) in the European Union (EU). Energy taxes act as levers of higher competitiveness 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, since 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 greater. On the contrary, pure environmental taxes do not emerge as a significant driver of the export dynamics. It is probably their lower weight compared with energy taxes and their 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. Since energy is still a necessary and non-substitutable input in the production function, provided that 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.

With regard to the low-tech sector, it is the only sector where both environmental and energy taxation do not play a role. In addition, anticipating comments on patents role, innovation also plays a weaker role. Low tech sectors are driven in their export performance by structural variables unrelated to innovation and policy.

As far as the role of private innovation strategies is concerned, the patent-based stock of knowledge positively affects export dynamics with one year lag: both the size and the significance of the coefficient are not negligible at all for high and also medium-high technology sectors. As long as some innovation efforts are induced by policy actions, this may constitute an indirect second level benefit arising out of regulatory efforts in environmental and related fields (energy, innovation, industrial policy).

Moving down along the technological ladder, the effect of innovation as it may be expected reduces its role. As far as medium-low technology sectors are concerned, lagged innovation covariates also confirm the same statistical significance, but showing on the other hand a weaker economic significance. Finally, the low technology sector as anticipated does not present significance for the innovative efforts, and also economic significance is lower compared with previous cases. Overall, innovation intensity as captured by a patent-based stock of knowledge positively shows fairly robust evidence across the four technological cases.

3.2 Green exports: the weak PH

3.2.1 Structural results

The results we comment on below come from the estimation of eq. (1) where the *k-th* sector is the export flows for the aggregate related to environmental goods. Environmental actions by private agents are modelled by using number of EMS and pollution abatement current expenditures (PACE) referring to HP2a (Table 2) whereas public policies are captured by environmental and energy levers as well as public expenditures in environmental R&D (HP2b, Table 3).[14]

With regard to the lag structure, AR tests confirm the two lags of the dynamic panel estimations. It is worth noting that the coefficient value for the second lag is lower compared with the strong PH where persistency over time seems to be stronger. This difference is a sign of the different role played by sunk costs in trade decisions by firms, considering that among environmental goods there are many products whose export flows have only very recently

[14] For comparison with international studies (Hamamoto, 2006), we have also tested - as sensitivity analysis – the role played by private actions (PACE and EMS) in the strong Porter hypothesis estimations, but results are not robust as expected. The absence of relevant correlation may well be explained by considering how narrow such private intervention is (as a sort of niche strategy for selected firms) compared with the broad range of manufacturing goods classified in the four technology-distinguished macro-sectors.

increased rapidly.

Mass is again often significant, as long as technological capabilities of the importing country, which turns out to be statistically robust with a negative sign as expected. As a matter of fact, in this case technological capabilities of the importing countries serve as barriers to trade. To some extent, provided that high endowment of technological capabilities is positively correlated with a higher demand for environmental goods, we can interpret this result as the higher capacity to satisfy demand for environmental goods by domestic production rather than 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 from 2005 onwards, is significant here; the positive sign of the coefficient cannot probably be stretched to support evidence of a correlation between ETS introduction and competitiveness. It may be that the positive economic cycle of 2005-2006 at world level and the increasing emphasis on green technologies and green investments are captured by this dummy.

3.2.2 Environmental policy and innovation drivers

With regard to the input innovation (R&D factors), general R&D expenses (one lag) turn out to be highly significant (in size as well) whereas specific environmental R&D lagged one year does not, but only in one regression. The same comments we provided for energy and environmental taxes may apply when 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 without producing over-identified instruments.

With regard to patenting activities considered here as the stock of knowledge based on total patents, the size of the coefficients is similar to that observed for (specific) patent intensity for different ‘technological’ classes. It is interesting 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, patent effectiveness in spurring green exports is positively influenced by the inclusion of 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 are 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.

Thus, in addition 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 did not find any significant effect. EMS has shown a quite strong increase in its diffusion recently. The problem may lie either with a low substantial over formal effectiveness of EMS or with its heterogeneous nature across countries. Germany is the absolute leader and massively exports green products. Nevertheless, statistical regularities do not conform to an outlier case of this type in the EU.

Results of specifications that account for the effects of policies such as energy and environmental taxes and environmental R&D expenditures reinforce empirical evidence on the weak version of the PH (HP2b).

As far as energy taxes are concerned, coefficients are significant from both an economic and statistical point of view, when patent-based stock of knowledge or environmental R&D public expenditures are included. Thus energy taxes seem to weigh more than patents in determining green competitive advantages, supporting a fairly robust 'weak Porter idea' of the relationship between policy/regulatory burdens and green-based economic performances with such evidence. With regard to the general conditions required for environmental regulation setting stressed by the PH, when policies are market-based (as energy taxes are), internationally homogeneous (and this is also the case), and widely diffused, their pervasiveness also ensures their efficacy, starting an inducement effect on the technological pattern and on overall economic competitiveness.

The only case where energy taxes are statistically overwhelmed is when R&D is included; this confirms that the relative ranking favours R&D as an engine factor of competitiveness. Energy taxes, on the other hand, are not significant when environmental public R&D is included. This is of some interest since it may highlight the extent to which private and public actions – energy taxation and private efforts in R&D activities in this case - are complementary and not undermined by trade-offs in their effects whereas public policy actions may present conflicting tools. Finally, innovation efforts in a general and specific form confirm once more their role in determining economic-environmental competitive advantages at macro level.

>>INSERT HERE TABLE 2<<

>>INSERT HERE TABLE 3<<

Somewhat differently, when analysing environmental tax effects, their economic significance is reduced with regard to energy taxes as the coefficients (here interpreted as elasticities) are lower, 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 (such as environmental taxes and public expenditure in environmental R&D), the higher the likelihood of crowding out effects. Extensive (patents and R&D expenditures) and specific (environmental taxes) levers instead prove to be highly 'complementary': they both contribute to the enhancement of green competitive advantages.

In the end, with some different weights, that also depend on the complementarity or substitution features that characterise such levers with regard to other private or public drivers of competitive advantage, energy and environmental taxes effectively contribute to the explanation of green export performances. At least in this specific definition of performances, we support the weak side of the PH to a greater extent.

4. Conclusions

We have shown that, over the decade 1996-2007, overall evidence in support of the strong and weak Porter hypothesis can be found for the EU15 by focusing on sector-specific export dynamics since environmental policy actions seem to foster export dynamics rather than undermine EU competitiveness in international markets.

This is true even taking a relatively short term lens. Some negative effects of policies are ascertained, demonstrating gain that the PH is not to be taken for granted and is sector specific (and policy instrument specific as well); overall, the picture is nevertheless largely in favour of negligible or positive effects of policies on the EU competitiveness performance.

With regard to the strong PH, we provide original results by disaggregating effects across manufacturing sectors and exploiting diverse innovation and policy related drivers. Overall, the effect of environmental taxes does not conflict with export performances. In some cases, we observe positive relationships, in others negligible. More importantly, the high tech sector is the one that responds more positively to energy and environmental taxation whereas medium tech and low technology sectors are not negatively impacted.

Our results on the weak PH seem to confirm the possibility of a 'green competiveness' strategy for the EU, coherently with recent European environmental strategies as the Directive on Climate Change Actions, as well as the SET Plan. Environmental and energy taxation, regulatory effects captured by PACE, public R&D and patenting activities all generate various effects leading to enhancements of green competitive advantages. Overall, although the weight of public levers (regulations, taxes) is stronger than that of private innovations, both public and private actions are needed to drive green economic performances up.

These results seem to be very good news: such interventions, that may be structured in different ways according to different environmental policy strategy features, do not bring about indirect costs through 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 social benefits caused by environmental damage reductions minus compliance costs (tax burden, compliance costs, and innovation investments, among the others) is going to be positive with higher probability.

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

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Table 1 – EU export dynamics for technology-distinguished sectors (strong PH, HP1)

	High Tech		Medium-High Tech		Medium-Low Tech		Low Tech	
$Export_{ij(t-1)}$	0.46***	0.47***	0.45***	0.45***	0.38***	0.39***	0.45***	0.47***
	(14.70)	(14.88)	(14.10)	(13.49)	(11.19)	(11.72)	(11.38)	(12.76)
$Export_{ij(t-2)}$	0.20***	0.21***	0.27***	0.26***	0.17***	0.17***	0.26***	0.18***
	(6.28)	(6.36)	(7.65)	(7.65)	(5.29)	(5.29)	(6.54)	(3.39)
$Distance_{ij}$	-0.01	-0.05	-0.29**	-0.34***	-0.25**	-0.25**	-0.31***	-0.33***
	(-0.09)	(-0.53)	(-2.32)	(-3.52)	(-1.69)	(-1.96)	(-2.70)	(-3.09)
$Border_{ij}$	-0.39	0.46	-1.62	-1.93	2.77	1.36	-0.56	-1.30
	(-0.24)	(0.36)	(-0.95)	(-1.16)	(1.36)	(0.76)	(-0.57)	(-1.40)
$Mass_{ijt}$	0.21*	0.24**	0.42***	0.31***	0.53***	0.44***	0.24***	0.17**
	(1.91)	(2.31)	(3.35)	(2.90)	(3.46)	(3.83)	(2.72)	(2.04)
$Similarity_{ijt}$	0.27***	0.30***	0.31***	0.34***	0.30***	0.25***	0.17**	0.15**
	(2.67)	(3.16)	(3.14)	(3.94)	(2.94)	(2.77)	(2.30)	(2.28)
Rel. $Endow_{ijt}$	0.13*	0.09	-0.01	0.01	-0.02	-0.06	0.03	0.03
	(1.69)	(1.10)	(-0.17)	(0.05)	(-0.25)	(-0.85)	(0.73)	(0.66)
Firms Het. $_{ijt}$	-0.15	0.46	-0.05	0.49	-1.21**	-1.50***	-1.01	-1.02
	(-0.32)	(1.09)	-(0.10)	(0.91)	(-2.46)	(-3.08)	(-1.53)	(-1.60)
$Mills_{ijt}$	-0.03**	-0.04***	-0.01	-0.02*	-0.01	-0.01	0.01	0.01
	(-2.23)	(-3.05)	(-0.40)	(-1.69)	(-0.44)	(-0.09)	(0.10)	(0.37)
$Knowl_{iPAT(t-1)}$	0.18***	0.28***	0.17***	0.20***	0.13***	0.08**	0.07*	0.04
	(2.68)	(4.16)	(3.41)	(3.83)	(2.83)	(1.99)	(1.65)	(1.38)
$Knowl_{jt}$	0.08**	0.05	-0.01	-0.01	0.05	0.06	0.01	-0.01
	(2.18)	(1.36)	(-0.36)	(-0.37)	(1.19)	(1.57)	(0.05)	(-0.17)
$Ene\text{-}Tax_{i(t-1)}$	0.32*		0.14		0.30**		0.02	
	(1.68)		(1.08)		(2.04)		(0.12)	
$Env\text{-}Tax_{i(t-1)}$		0.20**		-0.15**		-0.12		-0.03
		(2.25)		-(1.97)		-(1.35)		-(0.47)
Euro	0.13***	0.10***	0.70***	0.73***	0.76***	0.80***	0.18***	0.19***
	(5.31)	(4.18)	(21.96)	(23.17)	(21.17)	(21.00)	(8.46)	(9.72)
Ets	0.26***	0.18***	-0.25***	-0.24***	-0.19***	-0.17***	0.31***	0.28***
	(4.89)	(3.84)	(-9.92)	(-9.74)	(-6.46)	(-5.57)	(5.77)	(5.55)
Oecd	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No Obs.	15,132	15,132	15,273	15,273	15,105	15,105	14,417	14,417
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)
Sargan test	28.28	24.74	23.73	23.34	19.57	17.32	175.70	131.51
	(0.40)	(0.59)	(0.31)	(0.33)	(0.55)	(0.69)	(0.00)	(0.00)

*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. Sargan Chi-sq test for over identification of restrictions (number of instruments).*

Table 2 – EU export dynamics for environmental goods, private actions (weak PH, HP2a)

	(1)	(2)	(3)	(4)	(5)	(6)
$Export_{ij(t-1)}$	0.54***	0.22**	0.51***	0.46***	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*	0.05**	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)
$Mass_{ijt}$	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**	-0.98**	-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)			
$Pace_{i(t-1)}$				0.27***	0.18*	0.06
				(2.97)	(1.77)	(0.92)
$Knowl_{iPAT(t-1)}$	0.08			0.13**		
	(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	-0.01	-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*	0.10***	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.	15,333	14,447	15,333	15,453	14,567	15,453
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)
Sargan 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. Sargan Chi-sq test for over identification of instruments.*

Table 3 – EU export dynamics for environmental goods, public policies (weak PH, HP2b)

	(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)
$Mass_{ijt}$	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.	15,453	14,567	15,453	15,453	14,567	15,453
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)
Sargan 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: 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. Sargan Chi-sq test for over identification of instruments.*

APPENDIX

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

Macro sector	Sector	ISIC Rev. 3	NACE	PATENT 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 – Definition of variables

Variable	Definition	Source
	Dependent variables	
$Export_{ijt}$	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	
$Distance_{ij}$	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*)	
$Mass_{ijt}$	$mass_{ijt} = \ln(GDP_{it} + GDP_{jt})$ (*time variant, sector invariant*)	
$Similarity_{ijt}$	$sim_{ijt} = \ln\left[1 - \left\lvert\left(\frac{GDP_{it}}{GDP_{it}+GDP_{jt}}\right)^2 - \left(\frac{GDP_{jt}}{GDP_{it}+GDP_{jt}}\right)^2\right\rvert\right]$ (*time variant, sector invariant*)	World Bank WDI
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*)	
	Environmental measures: Public policies and private actions	
$Ene\text{-}Tax_{it}$	Energy tax revenues as percentage of total revenues (*time variant, sector invariant*)	EUROSTAT
$Env\text{-}Tax_{it}$	Environmental tax revenues as percentage of total revenues(*time variant, sector invariant*)	
$Pace_{it}$	Pollution abatement and control expenditures as percentage of GDP (*time variant, sector invariant*)	
$Emas_{it}$	Number of Eco-Management and Audit Scheme initiatives by private firms as percentage of GDP (*time variant, sector invariant*)	
	Public and private innovation measures	
$Knowl_{iPATt}$	$INN_{it}^{k} = \sum_{s=0}^{t} PAT_{is}^{k} e^{[-\beta_1(t-s)]}$ Stock of knowledge function calculated on patents number (*time variant, sector specific*)	OECD-EUROSTAT
$Knowl_{iR\&Dt}$	Gross expenditures for R&D as percentage of GDP (*time variant, sector invariant*)	
$Knowl_{iR\&Denvt}$	Public environmental R&D efforts as percentage of GDP. (*time variant, sector specific*)	
$Knowl_{jt}$	inn_{jt} index calculated as eq. (6) (*time variant, sector invariant*)	

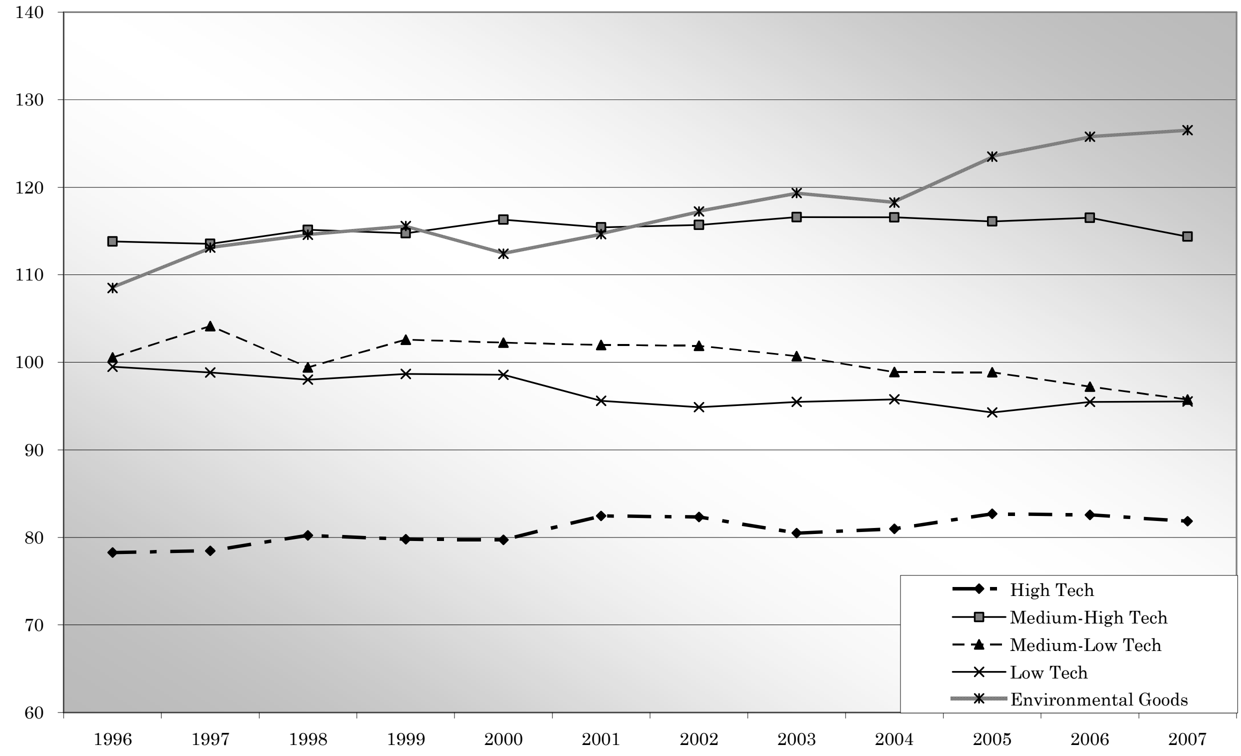
Table A3 – Descriptive statistics

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 A4 – Correlation Matrix

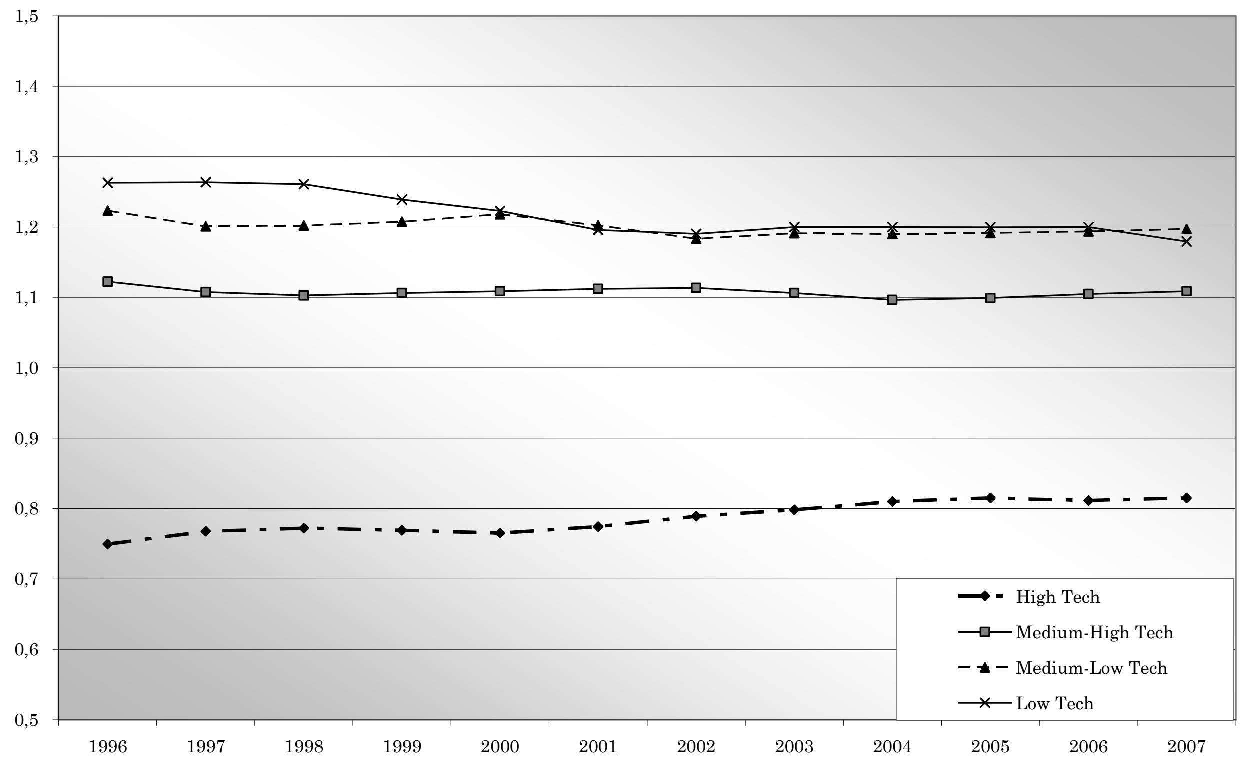
	Mass	Similarity	Rel Endow	Inn_j	Ene. Tax_i	Env Tax_i	$Emas_i$	$Pace_i$	$RDEnv_i$	RD_{TOTi}	Pat_{TOTi}	Pat_{SEC1i}	Pat_{SEC2i}	Pat_{SEC3i}
Similarity	-0.24													
Rel Endow	0.26	-0.28												
Inn_j	-0.24	-0.16	0.03											
Ene. Tax_i	0.22	-0.14	-0.05	-0.07										
Env Tax_i	-0.49	0.28	0.05	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

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.

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